DOCUMENT RESUME

ED 389 530 SE 056 857

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TITLE Student Outcomes and the Professional Preparation of Eighth-Grade Teachers in Science and Mathematics. NSF/NELS:88 Teacher Transcript Analysis.
INSTITUTION Westat, Inc., Rockville, MD.
SPONS AGENCY National Science Foundation, Arlington, VA.
PUB DATE May 95
CONTRACT RED-9255255
NOTE 112p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS Educational Environment; Grade 8; Junior High Schools; Mathematics Instruction; Science Instruction; *Secondary School Teachers; *Student Characteristics; *Teacher Characteristics; *Teacher Education; Teacher Effectiveness

ABSTRACT

The purpose of this study was to investigate the importance of teachers' professional preparation in mathematics and science, particularly with respect to student outcomes as measured through student test scores. The study uses the base-line data collected in 1988 for the National Education Longitudinal Study, a national study of 24,599 students in the eighth grade. The following factors affecting science and mathematics learning are discussed in detail: student characteristics including attitudes, students' plans for the future, student behavioral characteristics, gender equity, and minorities; school environment characteristics including attention given to science and mathematics, assessment, and resources; teacher characteristics and practices including teacher preparation, cooperative learning, texts, and homework; and family environment. Other topics discussed include: teacher characteristics as measured through transcripts including types of courses taken and grade point averages; teachers' backgrounds and the classroom environment including content covered by teachers, approach to homework, teachers' use of time, teachers' attitudes, patterns in teacher and student assignments, and influence of teachers on student attitudes; and teacher's background and student outcomes including inequalities in teachers assignments and student outcomes and multiple regressions. Ten appendices include: a description of NELS:88; the reliability of survey estimates, a comparison of transcript-based measures against teachers' self reports, academic degrees, and teacher certification. Contains 73 references. (JRH)

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ED 389 530

Student Outcomes and the Professional Preparation of Eighth-grade Teachers in Science and Mathematics

NSF/NELS:88 Teacher Transcript Analysis

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NSF Grant RED-9255255

May 1995

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Acknowledgements

Modern research projects increasingly require team efforts, and this study is certainly a prime example. The National Science Foundation was especially instrumental in first funding the collection of the transcript data and in providing the encouragement and funding for this report; Richard Berry and Larry Suter in particular were very helpful in different phases of this study. The National Center for Education Statistics graciously cooperated in making available data beyond that normally included in the NELS:88 database. Rocco Russo was responsible for much of the original design of the transcript collection and coding. The initial development of the transcript database used to examine teachers' backgrounds required painstaking attention to detail by many coders, under the capable supervision of Sheila Heaviside. Gabriel Massaro was particularly helpful in reviewing the literature, and in writing much of the text appearing in Chapter 1. Several outside reviewers -- Joseph Crosswhite, Dorothy Gilford, Senta Raizen, Kenneth Travers, and Iris Weiss -- and several colleagues at Westat (especially Kenneth Burgdorf and Julie Ehrhart) made many helpful comments on a preliminary version of this report, though they of course bear no responsibility for any errors that may remain. The physical attractiveness of this report is thanks to the speedy and accurate typing of Sylvie Warren. Finally, any study based upon survey research is ultimately dependent on the good will and cooperation of the survey respondents -- in this case, students, parents, teachers, and administrators -- who provide the data that is the foundation for the analysis.

Executive Summary

Description of Study

The purpose of this study is to investigate the importance of teachers' professional preparation in mathematics and science, particularly with respect to student outcomes as measured through student test scores. A complicating factor is that substantial disparities were found in teacher assignments, so that the students who might be predicted to perform best tended to have the teachers with the strongest backgrounds. For this reason, additional data about the students and their home and school environments are included to establish appropriate statistical controls for the other factors that might affect student outcomes.

This study uses the base-line data collected in 1988 for the National Education Longitudinal Study of 1988 (NELS:88), a national study of 24,599 students in the eighth-grade, including student test scores and data from the students and their teachers, parents, and school principals. Student cognitive test scores were obtained in four subject areas in the spring of 1988: science, mathematics, reading, and history. Data from the postsecondary transcripts of the students' science and mathematics teachers were also used to develop scales describing their professional preparation for teaching. While NELS:88 is a longitudinal study, this study uses only the cross-sectional data for 1988.

Because of the large number of students in the NELS:88 sample, almost all findings are statistically significant, whether or not they are substantively important. In order to avoid giving undue importance to small variations in the data, this report focuses on the general patterns found in the data, either across multiple disciplines or across a continuum of responses by the students or their teachers. However, a characteristic of the NELS:88 test data is that differences in mean student test scores typically appear small in magnitude, even for factors known to have great importance. Thus, this research pays less attention to the magnitude of the differences than to the general patterns that are found.

The primary focus of this report is on the NELS:88 teacher data. However, because NELS:88 was designed to provide a nationally representative sample of students, and not of teachers, this report presents statistics in terms of the number or percentage of students affected. This sometimes leads to awkward phraseology in describing the survey results.

Factors Affecting Science and Mathematics Learning in the Eighth-Grade

The literature on science and mathematics education as well as the NELS:88 data were examined to develop a list of the types of factors that should be included in a reasonably comprehensive model to predict student outcomes. A large number of factors were identified. As might be expected from the literature, student characteristics were often more strongly related to student achievement than teacher characteristics, even though teacher characteristics were found to be important as well.

Some of the major relationships were:[1]

Student attitudes

- *Attitudes towards science and mathematics.* Students with positive attitudes toward the subject (those who usually looked forward to their class, were not afraid to ask questions, and believed the subject would be useful in the future) obtained higher average test scores than students with less positive attitudes. However, the data do not establish whether the positive attitudes were a source or a result of student success.

- *General attitudes.* Students' general attitudes towards themselves and towards life were related to their test scores. Some of the important attitudes were whether the student felt he/she had enough control over life, whether the student felt good luck was more important than hard work, and whether the student felt capable of doing things as well as others. The test score differences for these general attitudes often showed a greater magnitude than for the students' attitudes towards specific subject areas.

Student plans for the future

- Students who planned to finish college and students who expected to enroll in college preparatory programs in high school obtained higher mean scores than other students, while students who did not know their plans received among the lowest scores.

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[1] Because of the focus of this report, the following student and school characteristics were not analyzed extensively but only with respect to whether they should be included in a model designed to measure teacher effects. The first chapter also includes a preliminary examination of teacher characteristics and practices using teachers' self-reports on the teacher questionnaire, while the remaining chapters incorporate transcript-based measures of teachers' backgrounds.

Student demographic characteristics

- *Gender.* Males received slightly higher scores than females in science, and females received higher scores in reading.

- *Race/ethnicity.* Hispanics, African-Americans, and Native Americans received lower mean scores than did whites and Asians/Pacific Islanders. No special disadvantage was detected with regard to science and mathematics, but rather the differences appeared in all four of the tested subject areas.

Student study habits

- *Academic behavior.* Several components of students' academic behavior were related to differences in student test scores, including students' failure to complete homework, their being inattentive in class, and their being frequently absent or disruptive.

- *Television.* Increased hours of television watching were associated with lower student test scores.

School environment

- Students tended to receive the highest test scores at schools where: the students placed a priority on learning; teachers had no difficulty motivating students; teachers responded to individual needs; and students faced competition for grades.

Teacher characteristics and practices

- *Highest degree.* No pattern was found in student test scores based on the highest degree the teacher had earned.

- *Subject area studied.* Students received higher mean mathematics scores if their mathematics teachers majored in mathematics as undergraduates or graduate students, and somewhat higher mean science scores if their teachers majored in science as graduate students.

- *Training in pedagogy.* In general, teachers' training in pedagogy was only helpful if the teacher had training in the subject area as well.

- *Teacher practices.* Students tended to perform better if their teacher felt well prepared, if their science teachers spent 2 hours per week conducting lab periods, and if their teachers emphasized certain topics (such as algebra, integers, and problem solving in mathematics, and chemistry and atomic theory in science). However, some of these results may represent differences in students' course-taking behavior, with academically weaker students taking courses with different emphases.

- *Homework.* Students generally performed better if their teachers assigned more than 1 hour per week of homework, and if the homework was discussed in class.

Classroom characteristics

- Certain characteristics of textbooks were found to be related to student performance, and especially whether the textbooks were not too difficult for the class and whether they were interesting to most students.

Family environment

- Students tended to have higher scores if their parents had high academic goals for the students, if students discussed programs at school with their parents, if parents attended a school event, and if the family had educational resources such as a computer.

Teacher Characteristics as Measured Through Transcripts

Two different methods were used to characterize teachers' academic background in science and mathematics. First, teachers were examined with respect to the types of courses they had taken in the subject area and in science and mathematics education, with an initial hypothesis that teachers might be considered best prepared if they had strong backgrounds in both the subject area and pedagogical training, least prepared if they had weak backgrounds in both areas, and in between if they had strong backgrounds in one area but not in the other.

- *Background in science and science education.* Most science students (61 percent) had teachers with at least some coursework in both science and science education, and roughly half (48 percent) had teachers with more than 40 semester credits in both areas combined. Only 2 percent of students had teachers with no courses in science.

- *Background in earth and physical sciences.* Because many teachers received their science training in the life sciences, only a relatively small percentage of students (11 percent) had teachers with over 40 semester credits in the earth and physical sciences -- the primary emphasis of eighth-grade science courses. Another 28 percent of students had teachers with between 20 and 40 credits in the earth and physical sciences, an amount that might be roughly equated with an undergraduate minor.

- *Background in mathematics and mathematics education.* In mathematics, 66 percent of students had teachers with backgrounds in both mathematics and mathematics education, a somewhat higher proportion than the equivalent for science teachers (61 percent). Roughly half (51 percent) of all mathematics students had teachers who might be considered most qualified according to the model above, with both a strong mathematics background (in terms of having taken courses beyond the level of calculus) and a background in mathematics education. However, when compared with science, there were also greater percentages of students whose teachers had no background in the subject area (5 percent), or in mathematics education only (5 percent).

Teacher backgrounds were also examined with respect to their grade point averages (GPAs) in the subject areas. This provides a measure of teachers' "success" in the subject area, independent of the number or level of courses taken.

- *Teachers' GPAs in science.* An estimated 12 percent of science students had teachers with science GPAs of 3.6 or higher, while 50 percent had teachers with GPAs ranging from 2.6 to 3.5, and 38 percent had teachers with GPAs of 2.5 or lower.

- *Teachers' GPAs in mathematics.* A slightly higher proportion of mathematics students had teachers with mathematics GPAs of 3.6 or higher (19 percent), while 49 percent had teachers with GPAs ranging from 2.6 to 3.5, and 31 percent had teachers with GPAs of 2.5 or lower.

Teachers' Backgrounds and the Classroom Environment

The differences that were found in teachers' backgrounds were examined to determine whether they were associated with what happened in the classroom: teachers' use of instructional materials, their choice of topics, their use of time, or their attitudes toward science and mathematics.

Instructional materials

- Little difference was found among teachers in their use of instructional materials, whether based on the types of courses the teachers had taken, or on the teachers' GPAs in the subject area (where somewhat larger but inconsistent differences were found).

Major topics covered

- *Mathematics.* The areas that teachers reported treating as major topics were related to teachers' professional preparation.[2] Students were less likely to see algebra treated as a major topic if their teachers had taken neither advanced mathematics courses nor courses in mathematics education (54 percent) than if their teachers had training in at least one of these two areas (64-67 percent). Students were more likely to see algebra treated as a major topic if their teachers had GPAs above 3.0 in mathematics (71 percent) than if their teachers had GPAs of 2.5 or lower (59 percent).

- *Science.* In science, there were no strong patterns based on the types of courses teachers had taken. However, students were more likely to see chemistry and atomic theory treated as major topics if their teachers had high GPAs in science (49 percent and 45 percent, respectively) than if their teachers had low GPAs (38 percent and 35 percent).

Homework

- *Science.* Science students were more likely to have more than 2 hours of science homework per week if their teachers had high science GPAs than were students whose teachers had lower GPAs in science (32 percent versus 26 percent).

- *Mathematics.* In mathematics, students were least likely to have more than 2 hours of mathematics homework if their teachers had backgrounds in both mathematics and mathematics education (41-42 percent), and most likely if their teachers had taken advanced courses in mathematics but no courses in mathematics education (60 percent).

Teachers' use of time

- Generally, teachers' backgrounds were related to only small and inconsistent differences in their use of instructional time. However, mathematics students were more likely to receive 2 or more hours of instruction per week as a whole class if their teachers had high GPAs in mathematics (82 percent versus 77 percent), and science students were less likely to receive 2 or more hours of lab periods if their teachers had high GPAs in science (17 percent versus 22-24 percent).

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[2] Differences could have occurred either because different eighth-grade classes intentionally were designed to cover different subject matter (e.g., some but not all eighth-grade students take courses in algebra), or because teachers chose to emphasize certain topics based on their own discretion.

Teachers' attitudes

- A greater percentage of mathematics students had teachers who felt very well prepared if their teachers had taken both advanced mathematics classes and courses in mathematics education (91 percent) than if their teachers were missing one of these areas (75-80 percent). Similarly, a greater percentage of science students had teachers who felt very well prepared if their teachers had taken more than 40 credits in science and science education (68-69 percent) than if their teachers had taken fewer credits (37-38 percent).

Patterns in teacher assignments

- Disparities in teacher assignments were identified. Students whose teachers had the least preparation in mathematics were disproportionately at schools where more than 60 percent of students were minorities, while students whose teachers had the strongest backgrounds were disproportionately likely to have their classes described by their teachers as higher than average in achievement levels. In science, students whose teachers had GPAs above 3.0 in science were less likely to be in schools where more than 60 percent of students were minorities, or in classes with average achievement levels.

Teachers' Backgrounds and Student Outcomes

Teachers' differences in academic backgrounds can be related to student outcomes as measured through the NELS:88 proficiency exams. Because of the possibility that these differences could be due to disparities in teacher assignments, the relationships were examined both alone, and within more comprehensive regression models of factors affecting student outcomes.

- *Overall findings in mathematics.* Students whose teachers had taken advanced courses in mathematics performed better than those whose teachers had taken courses only at the calculus level or below. The highest mean standardized scores were for students whose teachers had taken both advanced mathematics courses and mathematics education (51.3), and the lowest for students whose teachers had taken neither (48.2). Students also performed better if their teachers had high GPAs in mathematics (51.9) than if their teachers had low GPAs (49.2).

- *Overall findings in science.* In science, students performed better if their teachers had high GPAs in science (51.4) than if they had low GPAs (49.2). There also was a consistent pattern of increasing mean scores as the teachers' background in the earth and physical sciences increased; this pattern was not as consistent if teachers' background in all of the sciences is examined.

- *Multivariate analysis.* The differences in student outcomes continued to appear even after controlling for inequalities in teacher assignments. This was true both for simple crosstabulations and when examined through multiple regressions. In the regression analysis, teachers' background in advanced mathematics courses was found to be statistically significant when predicting student test scores, while their GPAs and background in mathematics education were not. In science, both teachers' GPAs and their having taken over 40 credits in the earth and physical sciences were statistically significant when predicting student test scores, while their background in science education again was not.

TABLE OF CONTENTS

Page

Acknowledgments. i
Executive Summary. iii

  Description of Study iii
  Factors Affecting Science and Mathematics Learning in the Eighth Grade iv
  Teacher Characteristics as Measured Through Transcripts. vi
  Teachers' Backgrounds and the Classroom Environment. vii
  Teachers' Backgrounds and Student Outcomes ix

Introduction 1

1 Factors Affecting Science and Mathematics Learning in the Eighth-Grade 3

1.1 Student Characteristics. 4

  Attitudes 4
  Students' Plans for the Future 9
  Student Behavioral Characteristics 11
  Gender Equity 13
  Minorities. 14

1.2 School Environment 15

  Attention Given to Science and Mathematics. 16
  Assessment 19
  Resources. 21

1.3 Teacher Characteristics and Practices 23

  Teacher Preparation 24
  Teacher Practices. 27
  Cooperative Learning 30
  Texts 31
  Homework 32

1.4 Family Environment 36

2 Teacher Characteristics As Measured Through Transcripts. 39

2.1 Types of Courses Taken 39
2.2 Grade Point Averages in Science or Mathematics 44

3 Teachers' Backgrounds And The Classroom Environment 47

3.1 Content Covered by Teachers 47

Instructional Materials 47
Choice of Major Topics 49

3.2 Teachers' Approach to Homework 51
3.3 Teachers' Use of Time 54
3.4 Teachers' Attitudes 56
3.5 Patterns in Teacher and Student Assignments 56
3.6 Influence of Teachers on Student Attitudes 58

4 Teachers' Backgrounds And Student Outcomes 63

4.1 Inequalities in Teachers Assignments and Student Outcomes 66
4.2 Multiple Regressions 70

5 Summary 77

Bibliography 81

Appendix A Methodological Notes A-1

Description of NELS:88 . . . . A-1
Reliability of Survey Estimates A-4
Comparison of Transcript-Based Measures Against Teachers' Self Reports A-6

Academic Degrees A-7
Teacher Certification A-10

Introduction

This is the final report of the NSF/NELS:88 Teacher Transcript Analysis, a study funded by the National Science Foundation. The primary purpose of this study was to develop measures of teachers' academic preparation for teaching eighth-grade science and mathematics classes, using data collected from the teachers' postsecondary transcripts, and to relate differences in teachers' academic preparation to their teaching practices and ultimately to student outcomes, as measured through student test scores. Of course, many factors are known to affect student achievement, and an analysis of teacher influence must account for these factors if teacher influence is to be properly measured. Fortunately, the NELS:88 database is an extremely rich source of data, with information collected from students, their teachers, their parents, and their schools; this study sought to incorporate such data while still retaining its focus on teachers' academic backgrounds.

Chapter 1 of this report provides a general overview of previous literature and of the NELS:88 data, with the intention of identifying those variables that should be included in a study of student outcomes. Chapter 2 begins the analysis of the NELS:88 transcript data to describe teachers' academic backgrounds, and provides summary information on the extent of teachers' preparation for teaching eighth-grade science and mathematics. Chapter 3 examines the interrelationship between teachers' academic backgrounds and the classroom environment, including the degree to which teachers' backgrounds are related to the content covered by teachers and the practices used in teaching. Chapter 4 examines teachers' influence on student outcomes, first by looking only at teachers' academic backgrounds and then by including multivariate controls for other factors influencing students. Finally, a methodological appendix describes the NELS:88 database, and discusses the creation of transcript-based measures of teachers' academic backgrounds.

1.

Factors Affecting Science and Mathematics Education in the Eighth-Grade

Many Americans are not scientifically literate. According to a recent poll, one-half of the public did not know that the earth revolves around the sun once a year, and one-half mistakenly believed that early humans lived at the same time as the dinosaurs.[1] Of particular concern are the students now moving through the educational system.

Two decades of data from the National Assessment of Educational Programs (NAEP) show that despite upturns in the 1980s, the average science achievement scores of students at age 17 in 1992 remained below 1969 scores and about the same for 13-year-olds.[2] However, the achievement of 9-year-olds is higher than it was in the 1969-70. The average mathematics proficiency scores followed a similar trend for age 17, with a decline between 1973 and 1982, followed by a recovery up to 1973 levels. The results were more positive for ages 9 and 13, with improvements between 1973 and 1992. One of the natioon's stated goals is to be first in the world in science and mathematics achievement by the year 2000; however, although international studies are fraught with methodological problems and limited in their ability to compare different cultures, U.S. students at age 13 were at the IAEP average in science in 1992, and just below the average in mathematics.[3]

The purpose of this chapter is to review existing literature and the NELS:88 baseline data to identify what types of variables should be included in the examination of student cognitive outcomes in science and mathematics. Though the primary focus of this study is upon teachers' professional preparation for teaching, the research literature provides ample evidence that there are many factors related to student performance, and unless these factors are accounted for, teachers' influence either may not be detected or may spuriously appear as the result of some other relationship. For example, if some types of teacher preparation are positively related to student performance, it may be because the students who perform the best who are assigned the "best-prepared" teachers (regardless of whether the preparation actually is useful). This chapter will not attempt to look at each factor that is related to student performance exhaustively; rather, the purpose is to develop a list of variables that should be included in a model that tests the importance of teachers' professional preparation. Only variables that are found to be important will be included in a multivariate model to be presented in Chapter 4. For example, some research has shown class size to affect student outcomes while other research has not; the NELS:88 data do not show a relationship (at least, upon initial examination), so it is not included in the model to examine the importance of teachers' professional preparation.

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[1] Rutherford, F. James, and Andrew Ahlgren. *Science for All Americans*, New York: Oxford University Press, 1990.

[2] Educational Testing Service. *NAEP 1992 Trends in Academic Progress*, Office of Educational Research and Improvement, Washington, DC: U.S. Department of Education, July 1994. See also Raizen, Senta A. "The State of Science Education." *Science Education in the United States: Issues, Crisis, and Priorities*, S.K. Majumdar, et al., Eds., Easton, PA: Pennsylvania Academy of Education, 1991.

[3] Lapointe, Archie E., Nancy A. Mead, and Janice M. Askew. *Learning Mathematics*, Educational Testing Service, Princeton, NJ, February 1992. Lapointe, Archie E., Janice M. Askew, and Nancy A. Mead. *Learning Science*, Princeton, NJ: Educational Testing Service, February 1992.

We will look at four broad categories of variables: student characteristics, the school environment, teacher characteristics, and the family environment. For each area, we will present a discussion of issues raised in the general literature on the topic, followed by an examination of data available from the NELS:88 baseline study.

1.1 Student Characteristics

Attitudes

Attitudes about science and mathematics appear clearly related to student performance. According to some research, students who enjoy science are more apt to do well and take advanced courses.[4] Similarly, students who dislike or fear science and doubt their own competencies are more likely to do poorly and boycott science altogether (to the extent that curriculum requirements will allow). Attitudes and beliefs are powerful forces that enhance or undermine students' mathematics performance as well. Students who like mathematics and consider themselves competent at it are more apt to achieve highly and persist in advanced mathematics courses.[5] Students who dislike or fear mathematics and doubt their own competencies are often likely to achieve below their capabilities.

Attitudes create a self-perpetuating cycle: students with positive beliefs perform well, which makes them like the subject area and feel good about themselves; students with negative beliefs often fall farther behind, which reinforces their low expectations and sense of failure. By the time that students reach the eighth grade, this cycle makes it difficult to disentangle why attitudes and performance are related; attitudes could be a result of students' past (or current) poor performance, or they could be a cause of it.

How do these attitudes take root? Often they grow out of implicit and explicit messages students pick up in and out of school, from teachers, peers, parents, books, and the media.[6] Students can sense if teachers are insecure with science. Sometimes teachers develop negative attitudes about science because they were taught with methods that dampened their interests. The methods by which science is taught can also be important. In one survey, 21 percent of students cited teachers as a reason why they liked science.[7] On the flip side, 33 percent cited instructional factors, such as too much lecturing, as why they disliked science. When science is taught as a tedious inventory of facts and theories, it is perceived as dull and complicated. Instruction that overemphasizes competition can produce early experiences with failure, which in turn can breed a dislike for science and a lack of confidence about future success. Teachers inadvertently transmit their expectations about what students can and cannot do and students internalize them.

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[4] Garofalo, Joe. "Beliefs and Their Influence on Mathematical Performances." *Mathematics Teachers*, October 1989.

[5] Gabel, Dorothy, Ed. *Problem Solving. Vol. 5 What Research Says to the Science Teacher*, Washington, DC: National Science Teachers Association, 1990.

[6] Ibe, Richard E. *The Enduring Effects of Productivity Factors on Eighth Grade Students' Mathematics Outcome*, presented at annual meeting of the American Educational Research Association in New Orleans, LA, April 5, 1994.

Incorrect or damaging perceptions also fuel negative attitudes about science. One is that success in science stems from innate ability more than from effort, and that "normal" students are not cut out for the hard job of studying science. This attitude is particularly evident for girls and minority students. Another is that scientists are eccentrics. Some students show indifference to science to keep their status with their peers.

Similar explanations apply to mathematics. An emphasis on drill and practice, paper and pencil exercises, and multiple-choice tests can make mathematics seem dull and sterile. Negative messages from outside the school environment reinforce classroom experiences that are not stimulating. Parents may tell their children how difficult mathematics was for them; television programs may depict the mathematics whiz as a nerd. Taken together these experiences can quash student interest in mathematics.

Though attitudes can change by becoming either more positive or more negative, the general tendency is for students to become more negative over time. With respect to science, any parent can describe the delight little children take in observing the world around them and experimenting with its limits. Yet somewhere in the elementary grades, these positive attitudes appear to wither or find outlets apart from science. By the end of third grade, almost half of the students in one survey said they would not like to take science, and by the end of eighth grade, only one-fifth had positive attitudes toward science.[8] Enthusiasm and confidence about science tends to dwindle as students progress through schools.

Much the same patterns appear for mathematics. Numbers fascinate young children. Research shows that preschoolers can solve addition and subtraction problems, usually by counting or arranging objects, well before they grasp underlying concepts.[9] However, children often become turned off to mathematics, for different reasons at different ages. In elementary school, boys and girls say they like mathematics and are good at it. However, by sixth grade, negative attitudes have begun to set in. Although the majority of seventh and eighth graders surveyed in NAEP in 1986 claimed to like mathematics, fewer than half the students in either grade said they wanted to take more mathematics. Although most of the students believed mathematics was a factor in getting a good job, fewer than half expected to work in a career that required mathematics.

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[7] Linn, Marcia. "Science Education Reform: Building on the Research Base." *Journal of Research in Science Teaching, (Vol. 29, No. 8), 1992.*

[8] Shrigley, Robert L. "The Role of Attitudes in School Science Instruction." *Science Education in the United States: Issues, Crises and Priorities*, Easton, PA: The Pennsylvania Academy of Science, 1991.

The baseline NELS data demonstrate a clear association between students' attitudes toward science and mathematics and their achievement in these subjects: students who said they usually looked forward to class, were not afraid to ask questions, and believed the subject would be useful in the future obtained higher average science and mathematics test scores than students who did not express these positive attitudes (Table 1). These associations between attitudes and achievement were also evident for reading and history/social studies. It is not clear from these data, however, whether it was the positive attitudes that produced the higher achievement, the achievement/success that generated the positive attitudes, or perhaps some of both.

Table 1. Mean standardized NELS:88 cognitive test scores, by student attitudes

Student attitude	Mean cognitive test score			
	Science	Mathematics	Reading	History
Usually look forward to class				
Strongly agree	51.2	51.0	49.7	51.3
Agree	50.4	50.5	50.3	50.6
Disagree	50.2	50.5	50.9	50.0
Strongly disagree	48.8	48.4	49.8	48.6
Afraid to ask questions in class				
Strongly agree	45.3	45.7	45.3	45.4
Agree	47.8	47.8	47.3	46.4
Disagree	50.3	50.6	50.4	50.5
Strongly disagree	51.8	52.0	52.1	52.1
Subject will be useful in my future				
Strongly agree	51.9	50.9	50.8	49.5
Agree	50.6	50.4	50.7	51.1
Disagree	49.2	48.9	48.9	50.3
Strongly disagree	47.5	46.0	46.5	48.3

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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[9] Borasi, Raffaella. "The Invisible Hand Operating in Mathematics Instruction: Students' Conceptions and Expectations." *Teaching and Learning Mathematics in the 1990's*, Reston, VA: National Council of Teachers of Mathematics, 1990.

It should not be assumed that science and mathematics are "foreign" areas to students and thus unusually likely to be associated with negative attitudes. Rather, in NELS, students demonstrated generally similar attitudes toward all four subject areas (Table 2). This raises the possibility that general problems in the educational system (or in society) are responsible for the negative attitudes, rather than problems that are unique to science and mathematics. One exception to this general pattern, however, is that students were more likely to perceive English and mathematics as being useful to their future than the other two subject areas (84-88 percent versus 59-68 percent). Beyond this relatively large difference, students were slightly more likely to be afraid to ask questions in mathematics classes than in other areas, and were slightly more likely to look forward to science than to mathematics or English classes.

Table 2. Student attitudes towards NELS-tested subject areas

Student attitude	Percentage of students			
	Science	Mathematics	Reading	History
Usually look forward to class				
Strongly agree	19	15	14	18
Agree	42	42	43	41
Disagree	27	30	32	30
Strongly disagree	12	13	11	12
Afraid to ask questions in class				
Strongly agree	3	5	3	3
Agree	12	16	12	12
Disagree	55	52	56	54
Strongly disagree	31	27	28	31
Subject will be useful in my future				
Strongly agree	25	44	34	16
Agree	43	44	50	43
Disagree	22	8	11	30
Strongly disagree	9	4	4	11

NOTE: Percentages may not add to 100 because of rounding.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

As well as finding relationships between attitudes towards science and mathematics and achievement in these areas, the NELS data also confirm relationships between student test scores and more general attitudes such as locus of control and hard work (Table 3). As might be expected with such generalized measures, the relationships are not limited to science and mathematics: roughly similar relationships can be found in all four subject areas tested by NELS. Despite the lack of specific focus on science and mathematics, the differences in scores among the students were sometimes greater with these more general measures than with the attitudinal measures discussed earlier. Thus, on the item *Good luck is more important than hard work*, students who strongly disagreed scored eight points higher than those who strongly agreed, compared with a four- to five-point difference on the more subject-specific items. Again, as with the other attitudinal measures, the relationship between attitudes and test scores might appear either because the appropriate attitudes help a student to persist and perform well in the subject matter, or because a student's relatively high performance helps to encourage more positive attitudes.

Table 3. Mean standardized NELS:88 cognitive test scores, by general student attitudes

Student attitude	Percentage of students			
	Science	Mathematics	Reading	History
I don't feel I have enough control over my life				
Strongly agree (5%)	47.2	46.8	47.4	47.5
Agree (15%)	47.8	47.7	47.7	47.6
Disagree (47%)	50.2	50.3	50.1	50.1
Strongly disagree (33%)	51.4	51.4	51.6	51.6
Good luck is more important than hard work				
Strongly agree (3%)	43.9	43.3	43.1	43.2
Agree (8%)	45.1	44.9	44.1	44.3
Disagree (46%)	49.9	49.8	49.8	49.9
Strongly disagree (42%)	51.8	51.9	52.2	52.1
I'm able to do things as well as others				
Strongly agree (40%)	50.6	50.5	50.5	50.7
Agree (52%)	50.2	50.3	50.2	50.2
Disagree (7%).	47.5	47.2	47.5	47.3
Strongly disagree (1%).	45.4	45.5	46.3	45.7

NOTE: Percentages may not add to 100 because of rounding.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Students' Plans for the Future

One can examine students' plans for the future as a special category of student attitudes. Students' plans are related to the attitudes discussed above (e.g., a student with poor self-esteem or a low locus of control is unlikely to plan an academically demanding career, and a student who dislikes science is unlikely to plan a career in science). A student's career aspirations would be expected to affect his or her motivation to study: this is most clearly true when a student's planned future career specifically requires strength in science or mathematics, but also may more generally be true, as when a student who plans to attend college feels a need to show a strong academic record in all subject areas.

The NELS data show strong differences in test scores based on a student's plans for the future (Table 4). Students who planned on obtaining postsecondary education received much higher scores than those who did not expect to finish high school, with each additional expected increment of education associated with higher average scores. Similarly, students who expected to enroll in college preparatory or academic programs in high school received higher average scores than other students. Students' career plans were also important: the highest average scores were received by those expecting careers in science/engineering and those planning professional or managerial careers. Further, the lack of plans was important; students who did not know their plans for high school or their plans for a career received among the lowest average scores. As a general rule, there were not great variations among the four subject areas tested by NELS, so that a student's plans for the future did not have a specific bias for or against science and mathematics as compared with other subject areas. For example, even among students planning a career in science or engineering, there were some differences in the four subject areas (e.g., the students scored a mean of 56.7 in science and 54.9 in reading), but it would be an overstatement to say these students were strong in science but weak in reading; in fact, these students received the highest mean scores in *each* of the four subjects. Among other expected occupations, there generally was even less variation across the four subject areas.

Table 4. Mean standardized NELS:88 cognitive test scores, by students' future plans

Future plans	Mean cognitive test score			
	Science	Mathematics	Reading	History
How far in school a student expects to get				
Won't finish high school (1%)	40.9	41.1	40.1	39.7
Will finish high school (11%)	44.3	43.3	43.5	43.4
Vocational, trade, or business school (9%)	46.8	45.7	46.0	46.4
Will attend college (13%)	46.7	46.3	46.7	46.7
Will finish college (43%)	51.4	51.7	51.6	51.6
Higher school after college (23%)	54.0	54.7	54.4	54.3
High school program in which the student expects to enroll				
College preparatory/academic (29%)	54.7	55.2	54.7	54.8
Vocational, technical, or business (18%)	47.7	47.1	47.6	47.8
General high school program (14%)	50.1	50.2	50.4	50.5
Specialized high school (5%)	49.7	49.7	50.6	49.7
Other (8%)	47.1	46.5	46.6	46.5
Don't know (25%)	47.7	47.7	47.6	47.4
Kind of work student expects at age 30				
Craftsperson (4%)	47.0	46.1	45.2	46.6
Farmer/farm manager (1%)	47.5	47.4	46.7	47.0
Homemaker (2%)	47.7	47.6	49.2	46.9
Laborer/farm worker (1%)	46.2	44.9	43.8	44.2
Military/police/security (10%)	48.7	47.6	47.7	49.0
Professional/business/managerial (29%)	52.4	53.1	53.2	52.7
Business owner (6%)	50.4	50.5	50.5	51.0
Technical (6%)	51.4	51.2	50.5	50.8
Sales/clerical (3%)	46.1	47.4	47.6	47.1
Science/engineering (6%)	56.7	56.0	54.9	55.9
Service worker (5%)	47.0	46.7	47.7	47.1
Other (17%)	50.1	50.0	50.4	50.2
Don't know (10%)	47.1	47.1	46.7	46.5

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Student Behavioral Characteristics

The NELS teacher questionnaire also asked the teachers to evaluate each sampled student in terms of his/her academic behavior (Table 5). These characteristics are interrelated with the attitudes and motivation discussed previously, but are discussed here separately because they concern students' behavior, as evaluated by a teacher. The NELS data show that these behavioral characteristics are related to student test scores: among the factors showing the largest effects in terms of the number of students involved and the size of the difference in test scores were students' failure to complete homework, their being inattentive in class, and their being frequently absent or disruptive. (Another characteristic -- *student performs below ability* -- also showed large differences in student performance; however, it requires a highly subjective judgment by the student's teacher, and may actually simply represent the fact that the teacher observes the student as performing less well than *others*, rather than performing below his/her own ability. In that sense, it may be too circular a measure to use for predicting student test scores.)

Table 5. Mean standardized NELS:88 cognitive test scores, by teacher report of student characteristics

Student characteristic	Mean cognitive test score			
	Science	Mathematics	Reading	History
Student performs below ability				
Yes (26-28%)	46.2	45.1	45.7	45.6
No (72-74%)	51.9	51.9	51.6	52.2
Student rarely completes homework				
Yes (20-22%)	45.3	44.6	45.2	44.9
No (78-80%)	51.5	51.4	51.4	51.8
Student is frequently absent				
Yes (11-12%)	46.1	46.2	46.5	45.9
No (88-89%)	50.8	50.6	50.5	50.9
Student is frequently tardy				
Yes (6-7%)	45.3	43.8	44.9	45.1
No (93-94%)	50.6	50.4	50.4	50.7
Student is inattentive in class				
Yes (21-22%)	45.5	45.3	45.3	45.2
No (78-79%)	51.6	51.5	51.2	51.8
Student is frequently disruptive				
Yes (12-14%)	45.8	45.4	45.4	45.3
No (86-88%)	51.0	50.8	50.7	51.1

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Perhaps one of the primary competitors for a student's time and attention is television. A student's choice to watch a large amount of television might reflect a lack of good study habits or a decision that time spent on homework is not productive, perhaps because of poor previous performance. Thus, it should not be surprising that the NELS data also confirm a generally negative relationship between academic performance and watching television, with increased hours of television watching associated with lower test scores (Table 6). Except for an extremely small group of students (3 percent) who reported watching no television and who actually received lower test scores on average that most other students, the best average scores were among those students who watched no more than 2 hours of television per day on weekdays. Television did not seem to present the same threat on weekends as on weekdays, with the highest scores generally appearing among students who watched 2 to 4 hours per day; this may indicate that students had more time available for watching television on weekends or that the weekends were less likely to be spent on homework, in either case resulting in less competition between television and homework. Somewhat surprisingly, the same pattern appeared for weekends as for weekdays, with students who watched moderate amounts of television performing better than those who either watched more television or who watched less; further, the findings are less easily dismissed than those for weekdays based on the number of students involved. No information is available from NELS on the type of television shows that were watched (e.g., whether the students watched educational television), but these data may suggest either that television has some educational value at moderate levels or that there is some type of self-selection in terms of some types of students seeking the stimulation that is offered by television.

Table 6. Mean standardized NELS:88 cognitive test scores, by student use of television

Student use of television	Mean cognitive test score			
	Science	Mathematics	Reading	History
Number of hours watched on weekdays				
Don't watch television (3%)	49.4	49.0	49.2	49.0
Less than 1 hour per day (8%)	52.0	52.4	52.1	51.8
1-2 hours (22%)	52.6	52.9	52.5	52.1
2-3 hours (23%)	51.6	51.8	51.6	51.6
3-4 hours (18%)	50.7	50.7	50.9	51.0
4-5 hours (12%)	49.6	49.4	49.8	50.0
Over 5 hours per day (14%)	49.6	49.4	49.8	50.0
Number of hours watched on weekends				
Don't watch television (4%)	47.1	46.9	46.9	46.4
Less than 1 hour per day (6%)	50.0	49.5	49.8	49.6
1-2 hours (12%)	51.7	52.2	51.8	51.6
2-3 hours (17%)	52.4	52.7	52.5	52.3
3-4 hours (18%)	52.5	52.6	52.7	52.4
4-5 hours (16%)	51.8	51.9	51.7	51.8
Over 5 hours per day (26%)	48.9	48.9	49.0	49.5

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Gender Equity

Gender equity is a persistent challenge in science and mathematics teaching and learning. A host of studies confirm that as girls progress through the educational system, their achievement and enrollment in science and mathematics courses generally decline relative to that of boys.[10] By age 13, an achievement gap materializes in most science content areas, and by age 17, girls achieve at a significantly lower level than boys, especially in physics. Girls as a group develop more negative attitudes about science. By age 11, boys show a more positive view of science on interest surveys than do girls. Also, by high school, even when the number of mathematics courses taken is factored out, males score higher than females in mathematics knowledge skills, applications, and understanding. In 1986, only 13 percent of employed scientists, mathematicians, and engineers were women, although women made up 49 percent of all professional workers.[11]

Several studies have probed the reasons behind these patterns and have concluded that girls receive differential treatment when it comes to science and mathematics.[12] The roots of the problem begin well before formal schooling. Parental and societal attitudes, adult examples, and deep-seated myths about the respective proficiencies of girls and boys are just some of the factors that shape attitudes. The toys they play with, the tools they use, the books they read, the types of encouragement they receive, all affect children's perceptions. Once children enter school, their experiences are further influenced by classroom patterns. One study found that fourth grade girls were less likely than boys to be praised by teachers for correct responses in mathematics.[13] Another study found that 79 percent of student-assisted science demonstrations were carried out by boys.[14] According to one study, boys tended to take control of equipment in lab situations, with girls often relegated to the role of notetaker.[15] Texts, materials, and media reinforce messages that science and mathematics are male domains. Girls need only take note of the shortage of female role models among high-school teachers and department heads in science and mathematics, among scientists and mathematicians who volunteer in schools, and among those in technological, mathematics, and science careers. New studies suggest that efforts to reduce gender inequities may be paying off – i.e., the gap between male and female students may be getting smaller.[16]

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[10] Oakes, Jeannie. *Multiplying Inequalities: The Effects of Race, Social Class and Tracking on Opportunities to Learn Mathematics and Science*, Washington, DC: The Rand Corporation, 1990. Sadker, Myra, et al. "Gender Equity in the Classroom: The Unfinished Agenda." *College Board Review*, (170), 1994.

[11] National Science Foundation. *Women and Minorities in Science and Engineering*, Washington DC: Author, 1988.

[12] Wilson, Meg, Ed. *Options for Girls: A Door to the Future*, Austin, Texas: Pro-ed., 1992.

[13] Linn, *op. cit.*

[14] *Ibid.*

[15] *Ibid.*

[16] *Ibid.*

The NELS:88 data also show some gender differences in students' test performance, with males having slightly higher scores in science (50.6 versus 49.5) and females have higher scores in reading (51.1 versus 48.9; Table 7).

Table 7. Mean standardized NELS:88 cognitive test scores, by student gender

Student gender	Mean cognitive test score			
	Science	Mathematics	Reading	History
Male (50%)	50.6	50.2	48.9	50.4
Female (50%)	49.5	49.9	51.1	49.7

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Minorities

The demographics are clear. By the year 2020, if the present trends continue, members of minority racial and ethnic groups will increase to well over 50 percent of American students.[17] Research on minorities and mathematics and science achievement has focused mainly on African-American and Hispanic students. As early as the first and second grades, differences in mathematics achievement among minority and white students are evident.[18] By the end of second grade, a greater proportion of minority students have slipped below grade level, compared to white students. By the end of middle school, many minority students have fallen so far behind in mathematics that catching up may seem almost impossible. Even with recent gains, the average science proficiency of 13- and 17-year-old minority students remains substantially behind that of white students.[19] Schools in which minority students are the majority tend to have high proportions of low-income students, fewer resources, inferior facilities and equipment, less qualified teachers, and fewer advanced offerings. A recent study which focused on eighth grade African-American students emphasized that students' attitudes toward mathematics are related to their future enrollment in higher-level mathematics courses, and the need to foster more favorable attitudes.[20]

The NELS data confirm that, except for Asians/Pacific Islanders, minorities tended to perform relatively poorly; however, unlike the results for gender, the lower scores occurred in each of the four subject areas, and did not vary substantially from one area to another (Table 8). (Two exceptions were that Asians/Pacific

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[17] Bean, De Anna Banks. *Mathematics and Science: Critical Filters for the Future of Minority Students*, Washington, DC: The Mid-Atlantic Equity Center, 1985.

[18] National Science Foundation, *op. cit.*

[19] Bean, *op. cit.*

[20] Rech, Janice, F. "A Comparison of the Mathematics Attitudes of Black Students According to Grade Level, Gender, and Academic Achievement." *Journal of Negro Education*, Vol. 63, No. 2, 1994.

Islanders performed somewhat better in mathematics than they did in other subject areas, and African-Americans performed somewhat better in reading and history/social studies than they did in science and mathematics. Still, neither exception contradicted the general advantage of whites and Asians over other minorities.) Disadvantages for minority students thus appear to be more of a generalized phenomenon than something specific to science and mathematics.

Table 8. Mean standardized NELS:88 cognitive test scores, by student race/ethnicity

Student race/ethnicity	Mean cognitive test score			
	Science	Mathematics	Reading	History
Native American (1%)	43.9	43.8	44.6	44.2
Asian/Pacific Islander (4%)	51.8	53.6	51.2	51.9
African-American, not Hispanic (13%)	43.9	43.8	44.6	45.0
Hispanic (10%)	46.0	45.7	46.0	45.9
White, not Hispanic (72%)	51.8	51.8	51.7	51.6

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

1.2 School Environment

Just as the home environment can encourage or hinder a student, the school environment can also affect a student. Some aspects of a school's environment are clearly a matter of school policy, such as the approach the school takes toward discipline, while others are at most only marginally under a school's control, such as the characteristics of a student's peers at a public school. A difficulty with interpreting measures of the school environment, however, is that they could measure effects of the school environment on the student or, alternatively, they could simply be an indicator of some of the student's own characteristics. For example, if a school's level of student absenteeism is found to be an important factor, the reason may be either that students become less motivated when other students are absent, or that the students being tested are themselves often absent and are suffering academically because of their absences.

The NELS data show that several aspects of the school environment were related to students' cognitive test scores (Table 9). On average, students performed best at schools where, according to the principal, the students placed a priority on learning, teachers had no difficulty motivating students, teachers responded to individual needs, and students faced competition for grades. Students also did better at schools where discipline was emphasized, although the highest mean scores appeared when schools took an intermediate approach to emphasizing discipline. Students also performed the best at schools that had no problems with student tardiness or absenteeism.

Attention Given to Science and Mathematics

School administrators, board members, and teachers would likely agree that science and mathematics instruction is of critical importance. Yet schools can send signals that subvert this message or adopt policies that make effective science instruction difficult to carry out. Often, science is not treated as a core subject. Science may be given little time during the school day; especially in elementary grades, it may be taught every other day and often paired with social studies. At the middle school level, students may not receive instruction that links the concrete learning they acquired in elementary school with the more abstract concepts and critical thinking required in high school-level science and mathematics. Often schools do not recognize good work in science and mathematics to the same extent that they recognize success in other areas such as sports. Rewards that exist only for the best students may discourage others from trying. Research indicates that instruction is qualitatively different in high- and low-track classes.[21] Students in low-track classes have less exposure to more challenging goals such as inquiry and problem solving skills and less access to the teaching strategies that are most likely to generate interest and promote learning. Schools can turn this situation around in several ways. They might establish school-based rewards for learning, establish science and mathematics clubs, hold non-competitive events to promote science and mathematics, encourage teachers to implement instructional practices that will motivate students, form partnerships with business and industry, and reserve more time for science and mathematics instruction. None of this will happen unless school leaders believe there is a real need to improve student performance in science and mathematics.

As science and mathematics vie with other disciplines for time in a limited school day, educators, researchers, and scientists have taken a fresh look at how to integrate science and mathematics with other curricular subjects. Some researchers contend that integrated learning activities are more viable and attractive at the elementary and middle school levels. Mathematics and science are often natural partners with similar goals of building process and problem-solving skills. Mathematics can serve as a critical tool for studying science. In turn, science can provide real-life situations in which students can apply mathematics. Moreover, curricular integration need not begin with the mathematics or science class. Mathematics and science lessons can be embedded in classes whose primary focus is another subject.

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[21] Raudenbush, S.W., B. Rowan, and Y.F. Cheong, "Higher Order Instructional Goals in Secondary Schools: Class, Teacher, and School Influences." *American Educational Research Journal*, Vol. 30 (3), 1993.

Table 9. Mean standardized NELS:88 cognitive test scores, by characteristics of the school environment

School characteristics	Mean cognitive test score			
	Science	Mathematics	Reading	History
Discipline is emphasized				
1=Not at all accurate (2%)	47.7	47.6	48.2	47.2
2=Intermediate response (2%)	48.4	48.5	47.7	48.1
3=Intermediate response (5%)	51.2	51.6	51.2	51.4
4=Intermediate response (25%)	50.6	50.7	50.5	50.3
5=Very much accurate (66%)	49.9	49.8	49.9	50.0
Students place a priority on learning				
1=Not at all accurate (1%)	46.1	46.6	47.2	47.4
2=Intermediate response (4%)	47.1	46.8	47.3	47.2
3=Intermediate response (37%)	48.8	48.4	48.5	48.7
4=Intermediate response (42%)	50.6	50.7	50.7	50.7
5=Very much accurate (17%)	52.3	53.1	52.4	52.4
Teachers have difficulty motivating students				
1=Not at all accurate (10%)	52.6	53.0	52.7	52.9
2=Intermediate response (30%)	51.0	51.2	51.1	50.9
3=Intermediate response (38%)	49.0	48.7	48.9	49.0
4=Intermediate response (20%)	49.8	49.5	49.6	49.6
5=Very much accurate (2%)	47.0	47.3	47.6	47.1
Teachers respond to individual needs				
1=Not at all accurate (1%)	48.9	48.4	49.1	48.4
2=Intermediate response (3%)	48.2	49.1	49.1	48.0
3=Intermediate response (18%)	49.5	49.3	49.2	49.4
4=Intermediate response (49%)	50.1	49.9	49.9	50.0
5=Very much accurate (29%)	50.7	51.0	51.0	50.9
Students face competition for grades				
1=Not at all accurate (6%)	49.0	49.4	49.3	49.4
2=Intermediate response (12%)	49.1	49.0	49.2	49.4
3=Intermediate response (34%)	49.2	49.1	49.2	49.3
4=Intermediate response (36%)	50.6	50.6	50.5	50.5
5=Very much accurate (12%)	52.3	52.6	52.3	52.1
Degree student tardiness is a problem				
Serious (4%)	46.6	46.9	47.1	47.2
Moderate (29%)	48.7	48.4	48.5	48.4
Minor (52%)	50.5	50.6	50.6	50.6
Not a problem (14%)	52.3	52.5	52.4	52.6
Degree student absenteeism is a problem				
Serious (5%)	45.4	45.3	46.0	45.8
Moderate (26%)	48.2	47.8	48.1	48.1
Minor (49%)	50.6	50.5	50.3	50.5
Not a problem (21%)	52.3	53.0	52.8	52.6

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

The limited research on interdisciplinary programs suggests that students achieve as well as in traditional instruction, while student awareness of the relationships between subjects and the relevancy of mathematics increases.[22] There is also some evidence that the integrated approach increases communication and sharing among teachers.[23] It requires, however, that teachers and schools be flexible about scheduling, planning, and classroom organization. Clearly, teachers need adequate training and time, and quality programs and appropriate materials need to be available to them.

The NELS data do not specifically address curricular integration. However, since the eighth grade can be taught either through a self-contained classroom or through multiple teachers that change depending on the subject, NELS:88 did ask about the method of the classroom organization. One might speculate that there would be greater curricular integration in classes that are self-contained (defined by NELS as *the same students are taught by one or more teachers for all or part of the day*, as compared with departmentalized or semi-departmentalized structures, in which students are taught by a different teacher for each subject, for at least some of their subjects); on the other hand, self-contained classrooms do not necessarily involve curricular integration, and they may have teachers with less expertise in science and mathematics than in classrooms where a different teacher teaches each subject. The NELS data show that students in self-contained classes actually had the lowest mean scores in all four subject areas, possibly suggesting that the specialization associated with departmentalized and semi-departmentalized classes is an important factor for aiding cognitive test scores (Table 10). However, since relatively few students were in self-contained classrooms (2 percent), these data cannot be given a great weight; further, these differences in scores may be due to other school characteristics that correlated with are offering self-contained classrooms. For example, it may be that less time is spent on science in classrooms that are self-contained, though this would not explained the consistent finding across all four subject areas.

A third issue is the depth of content provided in the classroom. Teachers are the main facilitators of content, but often school policies, districtwide objectives, federal and state requirements, mandated textbooks, and testing policies influence what content is taught. According to research, most students in the elementary and middle grades do not receive enough mathematics content, particularly advanced content, to prepare them for further study.[24] Rather, much of mathematics instruction focuses on computational skills. According to one study, computational skills receive 10 times the emphasis that conceptual understanding or applications do.[25] Research also confirms the common-sense observation that the more time spent on mathematics content to be learned, the better the students perform. High-achieving students spend more time on concepts and applications and cover more topics, while students working below grade level receive a mathematics curriculum heavy on review and drill. Research has found that "good" teachers focus their lessons on clear and meaningful content, using demonstrations and examples relevant to the content being taught.[26]

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[22] Spence, Carolyn S. and Carol S. Martin. "Mathematics and Social Studies -- Learning Connections." *Arithmetic Teacher*, December 1988.

[23] *Ibid.*

[24] Ohanian, Susan. "Readin, Rithmetic." *Learning*, October 1989.

[25] *Ibid.*

Table 10. Mean standardized NELS:88 cognitive test scores, by method of classroom organization

Classroom organization	Mean cognitive test score			
	Science	Mathematics	Reading	History
Self-contained (2%)	48.5	48.2	48.7	48.6
Departmentalized (83%)	50.2	50.2	50.1	50.0
Semi-departmentalized (14%).	49.7	49.6	50.2	50.5

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Assessment

Assessing student progress and instructional quality is an important part of science and mathematics education that encompasses more than testing. It includes systematic teacher observation and "authentic" assessment, in which tasks assessed more closely parallel the learning activities and outcomes that are desirable in the science and mathematics classrooms. Assessment can be a powerful influence on curriculum and instruction. The format of the assessment and the uses to which results are put can guide how teachers teach and students study, especially when applied to decisions such as allocation of resources, admission to special programs, or receipt of the high school diploma.

While the importance of assessment is well accepted, considerable controversy surrounds the issue. One concern is methodology. Many researchers have become concerned that assessment is not being used well in most science and mathematics education programs.[27] Concerns center around whether assessment instruments, such as norm-referenced, standardized tests, are being used for too many purposes for which they were not designed, and whether the results of tests are being misunderstood and misapplied. Some researchers have asserted that the most common assessment formats, particularly standardized tests, reinforce outmoded or ineffective instructional practices.[28] As reforms, they suggest the increased use of performance-based assessment and the integration of assessment methodologies with instructional outcomes and curriculum content.

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[26] Linn, *op. cit.*

[27] Kulm, Gerald and Carol Stuessy. "Assessment in Science and Mathematics Education Reform." *Science Assessment in the Science of Reform*, Gerald Kulm and Shirley M. Malcolm, Eds., Washington, D.C.: American Association for the Advancement of Science, 1994.

A second controversy concerns the use of testing as a means of controlling the promotion or graduation of students. A number of states have established competency exams as part of the educational reform movement, with the intention of establishing standards that might improve school performance and providing some assurance that a certain level of skills can be expected from high school graduates.[29] Others argue that such tests act less as an incentive than as a barrier to disadvantaged students. One particular concern is that the most widely used standardized tests and textbook tests in science and mathematics tend to emphasize low-level thinking and knowledge, and that this has an extensive influence on science and mathematics instruction.[30] Further, the tests appear to influence instruction most in classes with high percentages of minority students, resulting in possible inequities in the instructional system.

Most tests are designed and used to rank-order students against each other, with the inevitable result that there are few winners and many that are perceived to be mediocre or losers.

Some information about assessment is available in the NELS baseline data, since the school questionnaires included information about uses of testing. For all four subject areas, the use of standardized tests to assign students to courses or programs was associated with lower cognitive test scores (Table 11), but the differences in mean scores were relatively small (i.e., 0.4 to 0.6). Somewhat larger differences appeared with respect to schools' use of competency tests to determine whether students would be promoted into the ninth grade or retained in the eighth; students had higher mean scores if their schools did not use competency tests in this manner. It is possible that selection bias had a negative effect on scores at schools using competency tests: if a large number of low-achieving students were retained in the eighth-grade, the retention of these students could lower the overall mean. However, NELS:88 did not collect data on the number of students retained.

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[28] Hudson, Lisa. "National Initiatives for Assessing Science Education." *Science Assessment in the Service of Reform*, Gerald Kulm and Shirley M. Malcolm, Eds., Washington, D.C.: American Association for the Advancement of Science, 1994.

[29] U.S. Congress, Office of Technology Assessment. *Testing in American Schools: Asking the Right Questions*, Washington, DC: US Government Printing Office, 1992.

[30] Madaus, George F., Mary Maxwell West, Maryellen C. Harmon, Richard G. Lomax, and Katherine A. Viator. *The Influence of Testing on Teaching Math and Science in Grades 4-12*, Center for the Study of Testing, Evaluation, and Educational Policy, Boston College, October 1992.

Table 11. Mean standardized NELS:88 cognitive test scores, by school testing policies

School testing policies	Mean cognitive test score			
	Science	Mathematics	Reading	History
Standardized tests used to assign eighth graders to high school courses/programs				
Yes (59%)	49.8	49.8	49.9	49.9
No (41%)	50.4	50.4	50.3	50.3
Level of influence test scores have on course and program assignment				
A lot (33%)	49.2	49.4	49.6	49.7
Moderate (45%)	50.6	50.4	50.3	50.3
A little (10%)	50.5	50.7	50.4	50.3
None (4%)	49.2	48.6	48.7	49.3
Eighth graders retained if fail test				
Science competency test				
Yes (6%)	49.7	49.3	49.7	49.0
No (94%)	50.1	50.1	50.1	50.1
Mathematics competency test				
Yes (17%)	48.1	48.1	48.3	48.0
No (83%)	50.5	50.5	50.4	50.5
Reading competency test				
Yes (17%)	47.7	47.6	48.2	47.7
No (83%)	50.5	50.5	50.4	50.5
History competency test				
Yes (6%)	49.2	48.9	49.0	48.6
No (94%)	50.1	50.1	50.1	50.2

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Resources

A large number of studies have examined the importance of resources to educational outcomes. The Coleman report found that most variations among students could be traced to individual differences among students, with very little independent influence of schools.[31] Though the methodology of that study was criticized, a large number of studies have failed to find a relationship between student achievement and school resources, as indicated by such factors as school expenditures and class sizes.[32]

The NELS data also fail to show a relationship between class size and student achievement, with very little difference between students with class sizes of 19 to 24, and those with classes larger than 24; moreover, both groups performed at least marginally better than students with class sizes of 18 or less (Table 12). Possibly, this negative finding for small class sizes is due to other class characteristics that may be correlated with small class sizes and low test scores, such as remediation.

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[31] Coleman, James S. *Equality of Educational Opportunity*, Washington, DC: Government Printing Office, 1966.

[32] However, Ronald F. Ferguson, after reviewing these studies, does find improved performance for class sizes in the low-20s. See "Paying for Public Education: New Evidence on How and Why Money Matters." *Harvard Journal on Legislation*, (Vol. 28), 1991. Other studies include: Frederick Mosteller and Daniel P. Moynihan, Eds., *On Equality of Educational Opportunity*, New York: Vantage Books Edition, 1972.

Table 12. Mean standardized NELS:88 cognitive test scores, by class size

Number of students enrolled	Mean cognitive test score			
	Science	Mathematics	Reading	History
18 or less (14-21%)	49.6	49.8	48.7	50.0
19-24 (30-31%)	50.9	50.4	50.3	50.6
More than 24 (48-58%)	50.0	50.0	50.3	50.4

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Another NELS finding illustrates the classic difficulty of separating the effect of school resources from individual differences among students: students received higher science scores if the condition of science equipment in their classes was either good or excellent than if it was fair or poor, and the lowest mean scores were from those classes that lacked science equipment (Table 13). However, this apparent support of the value of school resources is undercut by the fact that these same students showed similar patterns in their test scores for mathematics, reading, and history/social studies. One would not reasonably expect that the condition of science equipment would influence students' history scores; what is more likely is that schools that had a high amount of resources available in science also had a high amount of resources available in social studies. Multiple interpretations of the data are possible. The data are consistent with the explanation that achievement is related to school resources, but the data are also consistent with the explanation that both student achievement and school resources are determined by a third variable – the economic resources of the students' parents.

Table 13. Mean standardized NELS:88 cognitive test scores, by condition of science equipment

Condition of science equipment	Mean cognitive test score			
	Science	Mathematics	Reading	History
Excellent (13%)	51.9	52.4	51.8	52.2
Good (42%)	50.9	51.1	51.1	50.9
Fair (29%)	49.7	49.4	49.9	49.8
Poor (11%)	49.4	48.6	49.6	49.5
None available (6%)	45.4	44.8	45.2	45.1

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Another topic that has recently received a great deal of attention is the amount of time devoted to instruction. American students receive less instructional time in core subjects than in many foreign countries, both because the academic year is shorter and because of the amount of the school day devoted to non-core subjects.[33] Thus, it has been suggested that American students are disadvantaged both in the sense of receiving less instruction, and of being more likely to forget instruction from the previous year over the long summer break.

American schools do not vary greatly in the length of the academic year, but NELS:88 does provide data on the amount of instructional time in four types of classes. However, these data fail to confirm that the number of hours a class meets is important to a student's achievement (Table 14). In fact, students who received 5 or more hours of instruction per week received slightly lower mean test scores than those who had fewer hours of instruction. It may be that some of these students received a high number of hours of instruction because they were remedial students receiving special attention, but in any case an automatic correlation between increasing the hours of instruction and improved test scores is not confirmed.

Table 14. Mean standardized NELS:88 cognitive test scores, by number of hours per week that class meets

Number of hours	Mean cognitive test score			
	Science	Mathematics	Reading	History
3 hours or less (9-13%)	52.0	51.2	50.2	52.8
4 hours (28-33%)	51.1	51.3	51.3	51.5
5 or more hours (54-61%)	49.3	49.2	49.4	49.6

NOTE: The percentage of students in each category is provided in parentheses.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

1.3 Teacher Characteristics and Practices

Teachers are vital to the reform of education. No reform, no matter how well-planned, will succeed unless it affects the special relationship between teacher and student. A changing role for the teacher is at the heart of most of the reforms proposed for teaching and learning. In the new paradigm of education, the teacher is no longer the authority who imparts a fixed body of knowledge to students, but a facilitator and role model who guides students through the adventure of learning, encouraging them with questions and feedback and sharing their curiosity and excitement. In the effective science and mathematics classroom, the activity of finding out is as important as knowing the answer. A consensus is emerging from research about some of the qualities, knowledge, and skills that teachers should possess. This process of consensus building is far from complete. Researchers and educators agree that the most effective teachers are those who have some of the following attributes.[34] These teachers:

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[33] National Education Commission on Time and Learning. *Prisoners of Time*, Washington, DC: Author, April 1994.

- Are life-long learners;
- Are willing to learn from others including their students;
- Have a vision of how they want to change;
- Update their subject knowledge;
- Update their pedagogic content knowledge;
- Spend time reflecting on their own teaching strategies;
- Devise teaching strategies that are effective with the diverse learning styles their students may exhibit;
- Devise incisive questions;
- Understand how to assist their students make transitions;
- Choose materials and activities that will lead students to discoveries new to them;
- Model qualities they would like students to have;
- Observe skillfully students' learning processes; and
- Are able to assess students' progress in meaningful ways.

To empower teachers to implement a new role will require a substantial and renewed commitment to preservice preparation and new models of staff development.

Teacher Preparation

Common sense suggests that teachers ought to have a firm command of the subject they teach. Studies have made clear, however, that teachers' knowledge of underlying mathematics concepts is often fragmented and sometimes inadequate or distorted.[35] Other studies have indicated that many teachers would like more opportunities to update their subject matter knowledge.[36] Elementary teacher candidates can receive a bachelor's degree without ever learning the content expected of mathematics and science majors. Instead, subject matter knowledge is transmitted through mathematics and science courses tailored to education majors. Some states do not require elementary majors to have taken any mathematics or science content courses. Even some middle school teachers may have taken no mathematics or science courses because they may receive emergency certification. It is therefore unrealistic to expect teachers who have not had in-depth preparation in mathematics and science to explain concepts to students. Most of the major reports on reform call for a significant change in preservice and inservice education that will give teachers more solid grounding in subject matter.[37] Strengthening the qualifications of teachers is a key step towards upgrading their professional status.

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[34] Anderson, Hans O. "Reformation in Science in Teacher Education." *Science Education in The United States: Issues, Crises and Priorities*, S.K. Majumdar, et al., Eds., Easton, PA: PA Academy of Science, 1991.

[35] Driscoll, Mark J. and Brian Lord. "Professionals in a Changing Profession," *Teaching & Learning Mathematics in the 1990's*, National Council of Teachers of Mathematics, Reston, VA, 1990.

[36] *Ibid.*

While the general proposition that teachers should have a good command of the subjects they are teaching seems indisputable, the research literature relating teacher backgrounds to student performance is mixed. Several prominent studies and reviews have found little empirical association between teacher preparation and student outcomes.[38] However, several more recent studies have demonstrated relationships between teachers' background knowledge and their students' measured achievement. For example, Ferguson found statistical associations between teacher literacy and student achievement across a wide grade range using district-level teacher competency test data from Texas, and Hanushek, et al. found evidence of direct associations between Brazilian teachers' subject matter knowledge and student achievement in the same subject.[39] Similarly, Monk found significant associations between some aspects of high school mathematics and science teachers' self-reported collegiate and graduate school coursework and their students' tested achievement gains in these subjects.[40] However, none of these studies have looked carefully at relationships between middle school teachers' subject matter knowledge/preparation and their students' achievement, which is the subject of this paper.

While teachers' preparation will be examined primarily through the teacher transcript data in this study, the NELS data also provide some information about teachers' backgrounds: Table 15 fails to show any pattern in students' test scores in terms of the highest degree the teacher had earned, but this not surprising, since the subject area in which the degree was earned is not necessarily the same as the subject being taught. Table 15 does show a pattern in terms of the subject area studied. Students received higher mean mathematics test scores if their teachers majored in mathematics at either the undergraduate or graduate level, and students in science received somewhat higher mean scores if their teachers majored in science in graduate school.[41] Strictly speaking, these data do not establish causality – it may be that the best students receive the "best" teachers (in terms of professional preparation) -- but the data do help to justify a more detailed examination of teachers' preparation through the use of transcript data.

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[37] The Holmes Group. *Tomorrow's Teachers*, East Lansing, MI: Author, 1986. Mathematical Sciences Education Board, National Research Council. *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, Washington, DC: National Academy Press, 1989. Committee on the Mathematical Education of Teachers, The Mathematical Association of America. *A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics*, Mathematical Association of America, 1991. American Association for the Advancement of Science. *The Liberal Art of Science: Agenda for Action*, Author, 1990.

[38] See, for example, Coleman, J.S., *op. cit.*; and Hanushek, E.A., "The economics of schooling: Production and efficiency in the public schools." *Journal of Economic Literature*, (24), 1986.

[39] Ferguson, *op. cit.*, and Hanushek, E.A., Gomes-Neto, J.B., and Harbison, R.W. *Self-Financing Educational Investments: The Quality Imperative in Developing Countries*, typescript, 1992, cited in Monk, David H. Subject Area Preparation of Secondary Mathematics and Science Teachers and Student Achievement, *Economics of Education Review*, (Vol. 13, No. 2), 1994.

[40] Monk, *op. cit.*

Table 15. Mean standardized NELS:88 cognitive test scores, by teacher's academic majors and degrees

Teacher's majors and degrees	Mean cognitive test score			
	Science	Mathematics	Reading	History
Highest degree held				
Less than bachelor's (rounds to 0%)	49.7	52.0	49.3	53.7
Bachelor's (53-56%)	50.2	49.8	50.0	50.0
Master's (37-40%)	50.4	50.4	50.0	50.8
Education specialist (5-7%)	50.0	49.9	48.9	50.2
Ph.D. or first professional (0-1%)	43.0	48.7	52.0	46.5
Bachelor's degree				
Majored in subject area (41-66%)	50.3	51.4	50.6	50.8
Minored in subject area (19-27%)	50.4	50.2	49.7	50.1
Neither (15-31%)	49.9	48.2	48.8	48.4
Graduate degree				
Majored in subject area (20-35%)	50.9	52.0	51.5	51.9
Minored in subject area (11-13%)	50.2	51.3	50.0	50.4
Neither (55-68%)	49.9	49.7	49.3	50.0
Either bachelor's or graduate degree				
Majored in subject area (43-67%)	50.4	51.4	50.7	50.9
Minored in subject area (18-27%)	50.3	50.2	49.7	49.8
Neither (15-30%)	49.9	47.9	48.6	48.2

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

A more complex relationship must be considered when assessing the impact of courses in teacher education. Some teachers combine a major or minor in teacher education with a major or minor in science or mathematics, while others major in teacher education without any concentration in science or mathematics. Thus, preparation in teacher education should not be evaluated alone, but in conjunction with the teacher's preparation in the subject area. Table 16 shows that subject area training was always a characteristic of the teachers whose students had the highest scores, and teacher education training was sometimes a characteristic. For example, at the undergraduate level for mathematics and history, the highest mean scores appeared when teachers had a major or minor in the subject area, with only small differences based on whether those teachers also had a major or minor in teacher education. For reading, the highest scores appeared when teachers had a combination of teacher education plus a major or minor in English, but teachers with a major or minor in English still had students with slightly higher scores than for other teachers. For science, the highest scores appeared when teachers had both a major or minor in teacher education plus a major or minor in science, while teachers with only a major or minor in science had students with roughly equivalent scores as for other teachers. In sum, one might conclude that teacher education sometimes can be helpful, but only if the teacher has training in the subject area as well.[42]

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[41] The relatively small differences for undergraduate degrees in science may reflect the fact that teachers' preparation often was in biology, while eighth-grade science is primarily in the earth and physical sciences.

Table 16. Mean standardized NELS:88 cognitive test scores, by teacher's preparation in teacher pedagogy and in the subject area

Areas of teacher's major and minor	Mean cognitive test score			
	Science	Mathematics	Reading	History
Bachelor's degree				
Teacher education plus subject area (18-26%)	50.9	50.7	50.8	50.5
Subject area without teacher ed (35-44%) . .	50.0	50.9	50.2	50.6
Teacher ed without subject area (25-34%) . .	50.1	49.0	49.6	50.1
Other (5-11%).	50.3	48.9	48.8	47.6
Graduate degree				
Teacher education plus subject area (13-17%)	51.1	52.4	50.1	50.9
Subject area without teacher ed (12-22%) . .	50.6	51.0	51.9	52.0
Teacher ed without subject area (43-56%) . .	49.8	50.0	49.8	50.2
Other (17-23%)	50.3	49.6	48.8	50.1

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Teacher Practices

The National Council of Teachers of Mathematics noted in its report, *An Agenda for Action*, that mathematics teachers must have their skills strengthened. There should be a change in the mission of mathematics education. Instruction should move away from a fixed set of routine skills and arbitrary rules toward challenging students' power to analyze, reason, and comprehend. With this change in mission comes a shift in the role of teachers -- from dispensers of knowledge to facilitators of learning.

Teachers can use a variety of strategies to whet students' interest. Though relevance became an overused catchword during the late 1960s, it need not imply a lack of rigor. Relevance can focus on meaningful, real world topics. The research literature points to several other factors that can be positive influences on students.

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[42] Again, this preliminary look at teacher preparation is insufficient to establish causality, since the relationship may be due to the best students getting the "best" teachers. However, it does help to justify the structure that will be used later in this report of separating the effects of training in the subject area and training in pedagogy.

Students are more motivated when teachers have high expectations for them.[43] Active, hands-on learning and scientific inquiry processes are important as motivating factors. Teachers can motivate students by modeling the qualities they want students to possess. These qualities include enthusiasm, wonder, and persistence.[44] When a teacher expresses delight with the outcome of a student experiment, he or she does more to build confidence than do most test results.

The NELS data provide several types of information about teachers' practices in the classroom that can potentially be related to student achievement. Table 17 show there is a relationship between teacher preparation (as perceived by the teacher) and student performance, with students typically receiving higher mean scores when their teachers felt well prepared. Also, in science, students received the highest mean scores if their teachers spent 2 hours per week conducting lab periods, suggesting that the labs are important, but not to the exclusion of other teaching techniques.

Table 17. Mean standardized NELS:88 cognitive test scores, by teacher's attitudes and practices

Teacher attitude and practices	Mean cognitive test score			
	Science	Mathematics	Reading	History
How prepared teacher feels to teach				
Very well prepared (55-83%)	50.9	50.1	50.3	50.9
Well prepared (14-29%)	49.3	48.9	48.9	49.5
Adequately prepared (3-12%)	49.6	49.5	49.1	49.2
Somewhat prepared (0-3%)	51.2	45.3	49.0	47.1
Totally unprepared (rounds to 0%)	44.0	52.5	40.4	50.6
Time spent conducting lab periods per week				
None (12%)	48.3	-	-	-
Less than 1 hour (33%)	49.6	-	-	-
One hour (33%)	50.8	-	-	-
Two hours (16%)	52.0	-	-	-
Three hours (4%)	51.4	-	-	-
Four hours (1%)	51.2	-	-	-
Five or more hours (rounds to 0%)	48.6	-	-	-

- Outside of the sciences, at least 84 percent of students were in classes where no time was spent on lab periods.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Teachers' choices of topics to emphasize in their classes were sometimes important (Table 18). For example, students tended to receive lower mean scores if their teachers treated fractions, percentages, measurement, and geometry as major topics, and higher scores if their teachers emphasized algebra, integers, and problem solving. (Of course, there is probably some selection bias in these statistics, with the academically weaker students taking different types of mathematics courses than other students. In the eighth grade, some students would be taking algebra and others would not.) In science the differences were not as strong, but students received somewhat higher scores if, for example, their teachers emphasized chemistry and atomic theory, and lower scores if their teachers emphasized personal health and human biology.

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[43] Monk, *op. cit.*

[44] Anderson, *op. cit.*

Table 18. Mean standardized NELS:88 cognitive test scores, by teacher's choice of topics

Teacher's choice of topics	Mean cognitive test score by emphasis			
	Major topic	Minor topic	Review topic	Not covered
Mathematics: emphasis given to				
Common fractions (major topic: 61%)	47.2	51.3	55.8	61.2
Decimal fractions (60%)	47.4	51.7	56.3	55.7
Measurement (37%)	47.7	49.3	54.9	58.1
Percent (75%)	48.7	51.4	60.3	55.4
Ratio and proportion (64%)	49.2	50.3	58.1	48.8
Geometry (50%)	49.6	49.1	56.7	52.3
Probability/statistics (20%)	50.5	49.9	52.1	49.8
Problem solving (75%)	50.9	48.1	47.5	44.6
Integers (70%)	50.9	48.3	55.4	41.6
Algebra (62%)	52.9	46.6	45.0	41.9
Science: emphasis given to				
Personal health (10%)	48.9	49.0	50.3	51.0
Human biology (18%)	49.3	49.0	50.7	50.6
Plants (12%)	49.3	49.9	50.4	50.5
Science/society (21%)	49.5	50.7	50.0	50.2
Astronomy (49%)	49.6	50.1	49.8	51.4
Oceanography (33%)	49.6	50.5	49.6	50.7
Animals (14%)	49.7	49.6	50.7	50.5
Weather (43%)	49.8	50.2	49.4	51.0
Environmental science (31%)	49.8	50.6	50.2	50.4
Earth science (56%)	49.8	51.7	51.4	50.4
Electricity (30%)	49.9	50.6	49.9	50.4
Genetics (7%)	50.0	49.8	49.8	50.4
Heat (30%)	50.3	49.8	50.4	50.6
Mechanics (23%)	50.4	49.4	50.1	50.5
Atomic theory (40%)	50.6	50.5	50.0	49.3
Optics (19%)	50.8	49.7	49.1	50.6
Chemistry (44%)	50.8	50.4	50.1	48.4

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

In science, students performed somewhat better if their teachers performed demonstrations of science experiments every day than if they performed demonstrations once a month or less often, and even more so, if the students themselves conducted science experiments every day than if they conducted experiments once a month or less often (Table 19). This does not mean, however, that the entire class time was devoted to a lab period, since Table 17 showed that the highest scores appeared when the teachers spent 2 hours per week conducting lab periods.

Table 19. Mean standardized NELS:88 science cognitive test scores, by teacher's use of experiments

Teacher's use of experiments	Mean cognitive test score by frequency of experiments			
	Every day	Once a week	Once a month	Less often
How often teacher demonstrates science experiment	50.8	50.5	49.6	50.0
How often students conduct experiments	51.9	51.0	49.3	49.2

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Cooperative Learning

Some science and mathematics teachers are moving toward a cooperative learning approach in which small groups of three or four students work together on a problem or experiment. Cooperative learning seems to encourage students to share responsibility for learning. Students develop approaches and explanations, share information, talk and listen, argue and persuade. They learn to order their thoughts and compare their own thinking processes with their peers. Students also get involved with tutoring and encourage each other. Research shows that cooperative learning can result in higher achievement, greater self-confidence, better group relations, more cross-cultural integration, improved acceptance of mainstreamed students, and enhanced social skills.[45] A review of 80 small-group cooperative learning studies revealed that in more than 40 percent of the studies, cooperative learning students showed significantly higher achievement.[46]

The NELS data do not directly address whether students worked in groups. However, when teachers were asked whether their science classes had enough equipment for each student to have his/her own, the highest mean scores were among students in classes where two students shared equipment (52.0), though students did slightly better if each had his or her own equipment

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[45] Slavin, Robert E., et. al. "Cooperative Learning Models for the 3 R's." *Educational Leadership*, (Vol. 47, No. 2), Dec.-Jan. 1989-90.

[46] Spence, *op. cit.*

(50.4, but only 4% of the students) than if groups larger than two shared the equipment (49.9). The worst average scores, as might be expected, were at those schools where teachers had little or no equipment for students to use (48.3).

Texts

A number of studies have analyzed the ways in which textbooks drive curriculum and instruction.[47] The consensus is that reliance on some textbooks reinforces less effective teaching methods and contributes to the image of mathematics and science as dull, passive, and fact-oriented. A number of studies, most from the mid-1980s, examined the quality, content, and influence of widely used mathematics texts, and found them wanting in key respects.[48] The most popular were found to be long, wordy, repetitive, and superficial in their coverage. Most emphasized low-level computational procedures. When used exclusively, mathematics texts are insufficient. Most science texts cover an encyclopedic range of topics in a cursory and disconnected way, often impeding students' progress toward deep understanding of important core ideas. As scientific knowledge increases, texts become weightier and the coverage of topics more superficial. Science texts must undergo considerable revision if they are to improve their instructional effectiveness.[49]

More populous states are very important players in the improvement of textbooks when they adopt textbooks for use statewide. Twenty-two states adopt texts after reviewing them to see whether they are aligned with the state curriculum.[50] California has gone further by adopting multimedia materials for science and a multimedia curriculum for the middle grades.[51]

In NELS:88, teachers were asked several questions to evaluate the textbooks they used. Two textbook characteristics -- not being too difficult for the class and being interesting to most students -- were consistently associated with relatively high student test scores in all four NELS subject areas (Table 209). The four remaining textbook characteristics -- develops problem-solving skills, explains concepts clearly, has good suggestions for homework, and covers the subject well -- were also associated with relatively high test scores in mathematics. Student test performance in science and history was essentially unrelated to these latter dimensions, however, and performance in reading was only slightly related to them.

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[47] Nicely, Robert F. Helen R. Fiber, and Janet C. Bobango. "The Cognitive Content of Mathematics Textbooks." *Arithmetic Teacher*, 1988.

[48] *Ibid.*

[49] Pizzini, E.L., D.P. Shepardson, and S.K. Abel. "The Questioning Level of Select Middle-School Science Textbooks." *School Science and Mathematics*, 92 (2), 1992.

[50] Mullis, Ina and Lynn B. Jenkins, Eds. *Science Learning Matters: An Overview of the Science Report Card*, Princeton, NJ: Educational Testing Service, 1988.

[51] *Ibid.*

Homework

Teachers say they assign 10 hours of homework a week, on average.[52] But many students spend considerably less time than that on homework, and about 10 percent say they do none at all.

Studies in science generally have found that the amount of time spent on homework correlates with student achievement, although it may be hard to isolate the effect of homework from related factors, such as high student motivation and greater family support.[53] Nevertheless, homework increases the amount of time spent on science learning, and research confirms that the more time students spend on a subject, the better they perform, especially in the early years.

Some studies have found that mathematics achievement is higher when students have regular homework.[54] Just about as many studies have found no significant correlation between homework and achievement gains.[55] No studies have revealed negative effects from homework. Therefore, it seems reasonable to conclude that while time spent on homework may not be a strong predictor of student mathematics gains, homework does not hurt and may very well help. There is also some research showing that positive effects of homework may accumulate over time and that homework helps students become more independent learners.[56]

American students do not spend much time on science homework. One-third of elementary students who receive instruction in science said they spent no time on science homework, according to a 1986 national assessment.[57] Two-thirds of the 13-year-olds in another science assessment said they did less than 1 hour of science homework a week.[58] U.S. students spend much less time on homework than their international peers.[59] One study found that children in Asian countries spent 4 to 10 times as much time as first graders in Minneapolis, and that disparities increased in later grades.[60] Although the relationship between homework and achievement was not consistent across nations, the top three nations in one international science assessment also ranked highest on time students spent doing homework.[61]

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[52] Bybee, Rodger W., et al. *Science and Technology Education for the Middle Years: Frameworks for Curriculum and Instruction*, Andover, MA: The Network, 1990.

[53] Mullis, *op. cit.*

[54] Suydam, Marilyn N. "Homework, Yes or No?" *Arithmetic Teacher*, January 1985.

[55] *Ibid.*

[56] Driscoll, Mark J. "Securing Mathematical Skills: Drill and Other Topics." *Research Within Reach: Elementary School Mathematics*, St. Louis, MO: CEMREL, Inc., 1989.

[57] Bishop, John. "Scientific Illiteracy: Causes, Costs, and Cures." *This Year in School Science 1989: Scientific Literacy*, Washington, DC: American Association for the Advancement of Science, 1989.

[58] *Ibid.*

[59] *Ibid.*

[60] Mullis, *op. cit.*

[61] Commission on Precollege Education in Mathematics, Science, and Technology, National Science Board. *Educating Americans for the 21st Century*, Washington, D.C.: National Science Foundation, 1983.

Table 20. Mean standardized NELS:88 cognitive test scores, by teachers' opinions about their textbooks

Teacher's opinion	Mean cognitive test score			
	Science	Mathematics	Reading	History
Textbook level too difficult				
Strongly agree (2-5%)	46.5	49.2	43.7	46.6
Agree (8-14%)	48.1	47.0	46.3	48.4
No opinion (2-5%)	48.0	48.7	48.5	50.3
Disagree (57-61%)	50.5	49.8	50.0	50.5
Strongly disagree (20-27%)	52.4	52.7	52.0	52.4
Textbook develops problem-solving skills				
Strongly agree (7-16%)	51.0	53.1	51.0	50.5
Agree (49-63%)	50.1	49.9	50.2	50.6
No opinion (5-19%)	49.3	49.7	50.2	51.0
Disagree (14-23%)	51.1	48.5	49.5	49.6
Strongly disagree (2-4%)	49.7	50.8	49.4	51.0
Textbook explains concepts clearly				
Strongly agree (11-17%)	50.0	52.0	50.8	51.2
Agree (62-66%)	50.3	50.1	50.1	50.5
No opinion (5-7%)	50.7	50.0	50.4	51.0
Disagree (7-14%)	50.3	48.7	47.9	49.3
Strongly disagree (1-2%)	50.2	49.5	49.8	52.1
Textbook has good suggestions for homework				
Strongly agree (12-18%)	50.7	52.2	51.0	50.3
Agree (47-58%)	50.3	49.8	50.1	50.5
No opinion (7-12%)	50.2	50.4	49.2	50.2
Disagree (10-24%)	50.4	49.1	49.2	50.7
Strongly disagree (2-6%)	49.1	48.4	49.1	49.3
Textbook covers subject area well				
Strongly agree (20-24%)	50.5	52.9	51.2	50.8
Agree (59-63%)	50.3	49.8	49.8	50.4
No opinion (4-6%)	49.0	49.5	51.0	49.4
Disagree (11-12%)	50.4	47.9	48.7	49.8
Strongly disagree (1-3%)	49.8	48.9	48.2	53.5
Textbook interesting to most students				
Strongly agree (4-6%)	50.3	54.0	50.9	52.2
Agree (34-43%)	50.8	50.9	50.2	50.7
No opinion (21-31%)	51.0	50.2	49.9	50.7
Disagree (25-29%)	49.2	48.9	49.9	49.7
Strongly disagree (4-8%)	48.7	48.3	49.4	49.9

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

The quality of science homework is also important. One study found that 90 percent of homework in biology involves using the textbook, and textbooks have come under some serious criticism by educators of late.[62] Homework is more effective when teachers check it and provide prompt feedback. Research also suggests that homework is more valuable when it is checked and discussed in the family or when parents help with homework.[63]

Studies in mathematics have found that 1 to 3 hours of homework per week can make low-achieving students perform as well as average students who do no homework.[64] It appears to be most useful in improving students' computational skills. Short daily assignments seem to be the best form of practice. According to research, however, the practice of grading mathematics homework may be counterproductive.[65] The most beneficial approach may be for teachers to make home drill-and-practice activities risk-free; to credit students for doing homework and not punish them when they have difficulty. From the teacher's standpoint, homework cab be a primary source of information about a child's progress which the teacher uses to adapt instruction to students' needs.

The quality of mathematics homework is as important as the quantity.[66] Students are more willing to do homework when teachers treat it as an integral part of the curriculum and give back written comments. Students also take homework more seriously when they perceive assignments as useful. For instance, when assignments require students to think instead of just filling in worksheets the assignment is more meaningful. Teachers can use individualization to prevent students who have clearly mastered a skill from being consistently required to do busy work.

The NELS data show a generally positive relationship in each of the four subject areas between the amount of time spent on homework and students' test scores, except that students spending an extremely large amount of time (typically 7 or more hours) failed to fit in the general pattern (Table 21). Possibly, these are students whose amount of time spent reflects the students' own academic weakness (and thus who needed more time to accomplish the same task) rather than their motivation.

While the amount of time devoted to homework was important, the NELS data were less positive with respect to many uses of homework (Table 22). There were only minor differences based on whether teachers returned the homework with grades or corrections, with some of the highest scores among those students whose teachers never provided grades or corrections. The NELS data do suggest a positive value to discussing the homework in class; the lowest mean scores were from classes where teachers never discussed the homework (though few teachers were in this category), and the mean scores generally were higher as teachers gave increased attention to discussing the homework.

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[62] Commission on High School Biology Education, National Research Council. *Fulfilling the Promise: Biology Education in the Nation's Schools*, Washington, DC: National Academy Press, 1990.

[63] Corporation for Public Broadcasting. *TV Tips for Parents: Using TV to Help Your Child Learn*, Washington, DC: Corporation for Public Broadcasting, 1988.

[64] Driscoll, *op. cit.*

[65] *Ibid.*

[66] Corporation for Public Broadcasting, *op. cit.*

Table 21. Mean standardized NELS:88 cognitive test scores, by time spent on homework

Hours per week in subject area	Mean cognitive test score			
	Science	Mathematics	Reading	History
Time reported by student				
None (9-18%)	48.8	46.8	47.7	48.7
Less than 1 hour (42-47%)	50.2	48.9	50.0	50.2
1 hour (21-23%)	50.2	49.3	50.2	49.8
2 hours (9-11%)	52.2	53.2	52.5	52.0
3 hours (4-7%)	52.8	55.3	53.9	53.0
4-6 hours (2-7%)	53.2	56.3	53.6	53.3
7-9 hours (0-1%)	52.0	57.3	53.0	51.7
10 or more (0-1%)	48.8	53.6	50.2	47.9
Time assigned by teacher				
1 hour or less (science: 30%; others: 14-21%)	49.5	47.8	46.6	48.4
Up to 2 hours (38-42%)	50.6	49.2	49.8	51.0
More than 2 (science: 26%; others: 36-47%)	50.5	51.6	51.6	50.9

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 22. Mean standardized NELS:88 cognitive test scores, by teacher practices

Teacher practice	Mean cognitive test score			
	Science	Mathematics	Reading	History
Keep records of who turned in homework				
All the time (73-79%)	50.3	49.9	49.8	50.6
Most of the time (16-24%)	50.4	50.2	50.8	49.7
Some of the time (2-6%)	48.1	52.0	51.0	49.0
Never (0-2%)	48.5	51.7	44.7	50.7
Return homework with grades/corrections				
All the time (46-56%)	50.0	49.9	49.8	50.4
Most of the time (23-35%)	50.3	49.1	50.2	50.5
Some of the time (11-22%)	50.1	51.1	50.3	49.6
Never (2-9%)	52.3	51.3	50.0	52.5
Discuss homework assignment in class				
All the time (61-80%)	50.6	50.8	50.4	50.3
Most of the time (16-31%)	49.9	48.0	49.3	50.2
Some of the time (3-7%)	50.1	45.9	48.5	49.9
Never (0-2%)	48.0	45.4	44.5	47.8

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

1.4 Family Environment

Researchers have long noted that families have a critical influence on education.[67] In fact, Anderson and Berla say that it, and not income or social status, is the most accurate predictor of a student's achievement.[68] Families affect children in several ways: by establishing (or failing to establish) positive role models for the value of education, by supplying resources the student may use in education, by encouraging the student to perform his/her schoolwork, and by providing assistance to the student in completing schoolwork. So important is parental influence that one of the National Education Goals adopted by Congress is, *"Every school will promote partnerships that will increase parental involvement and participation in promoting the social, emotional, and academic growth of children."*

The NELS data confirm the importance of parental involvement, though they also show that one must distinguish between involvement that indicates a parent's interest in education and involvement that appears as a result of student problems. For example, the data show a positive effect of parents having high academic goals for the students, of students discussing programs at school with their parents, of parents attending a school event, and of the presence of educational resources such as a computer (Table 23). Also, if parents provide no limits on students' television viewing, then students receive lower test scores on average; however, the differences are smaller and sometimes in a negative direction if one compares parents who often limit television watching, those who sometimes do, and those who rarely limit it. Possibly, this may reflect that some parents are forced to limit television watching because of a student's poor school performance, so that establishing limits is less a sign of parental involvement than of the student's difficulties. Similarly, students tended to receive lower scores if their parents talked with a teacher or counselor, or visited a class, possibly because such parental activities were sometimes a result of poor student performance.

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[67] Stenmark, Jean Kerr, Virginia Thompson, and Ruth Cossey. *Family Math*, Berkeley, CA: Lawrence Hall of Science, 1986.

[68] Henderson, Anne T., and Nancy Berla. *A New Generation of Evidence: The Family is Critical to Student Achievement*, National Committee for Citizens in Education, 1994.

Table 23. Mean standardized NELS:88 cognitive test scores, by parental characteristics and activities

Parental characteristics	Mean cognitive test score			
	Science	Mathematics	Reading	History
Students discuss programs at school with parents				
Not at all (15%)	46.5	46.0	46.2	46.4
Once or twice (47%)	49.6	49.6	49.4	49.6
Three or more times (39%)	52.2	52.4	52.6	52.2
Student's parents spoke to teacher/counselor				
Yes (67%)	49.9	50.0	50.0	50.1
No (33%)	50.4	50.3	50.4	50.3
Student's parents visited classes				
Yes (30%)	49.7	49.8	49.7	49.7
No (70%)	50.5	50.4	50.5	50.5
Student's parents attended a school event				
Yes (63%)	51.6	51.8	51.7	51.7
No (37%)	48.0	47.6	47.9	48.0
How often parents check on student's homework				
Often (44%)	49.9	49.8	49.9	49.9
Sometimes (30%)	49.5	49.5	49.5	49.4
Rarely (16%)	51.0	51.4	51.2	51.1
Never (10%)	50.9	51.0	50.8	51.0
How often parents limit time watching television				
Often (14%)	50.7	51.0	51.0	50.8
Sometimes (23%)	51.0	51.0	51.1	50.9
Rarely (26%)	51.3	51.4	51.2	51.4
Never (37%)	48.4	48.2	48.3	48.4
Family has a computer				
Yes (42%)	52.5	52.8	52.2	52.4
No (48%)	48.6	48.4	48.8	48.6
How far in school the father wants student to go				
Less than high school (1%)	41.8	42.0	41.2	42.2
Graduate from high school (6%)	45.1	44.1	44.1	43.9
Vocational, trade, or business school (7%)	46.2	45.2	45.4	46.0
Attend college (11%)	46.5	46.2	46.1	46.5
Graduate from college (48%)	51.8	52.1	52.1	52.0
Higher school after college (27%)	52.6	53.0	52.9	52.8

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

2. Teacher Characteristics as Measured Through Transcripts

This chapter provides a general overview of the characteristics of eighth-grade science and mathematics teachers, as measured through transcript-based measures of teachers' academic preparation. Transcript-based measures are not the only way to examine teacher preparation -- for example, one may use teachers' self-reports of the degrees they have earned, their major fields of study, and the courses they have taken. However, transcript-based measures might be considered the most reliable: they are not subject to problems of recall or bias (as might be expected in teachers' self-reports), and the courses can be described through a carefully specified coding scheme using trained coders, while the teachers' own attempts to classify their courses might be subject to greater inconsistencies.[1]

When analyzing the transcripts, two different types of academic preparation were considered: one based on the types and number of courses that science and mathematics teachers had taken, and another on the grade point averages they had earned for courses in the subject area.

2.1 Types of Courses Taken

To measure the types and number of courses taken, a first distinction was to differentiate between coursework in the particular subject matter being taught (i.e., in science or mathematics) and courses in science or mathematics education. Additionally, teachers were classified based on the depth of their preparation. For mathematics, where course topics form somewhat of a hierarchy, teachers were classified as those who took courses only at the calculus level or below, or those who took advanced courses in mathematics. Science courses were less easily classified into a hierarchy based on the coding that was used, because a given course topic (e.g., physics or biology) may have been either an introductory course or an advanced course. Thus, science teachers were classified based on the number of semester credits earned in science and science education.[2] Also, because eighth-grade science courses are primarily devoted to the earth and physical sciences, while many teachers have a college background that primarily emphasizes the life sciences, some tabulations are presented on the number of credits earned in the earth and physical sciences.

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[1] For additional information on teacher errors on reporting and coding their academic preparation, see Chaney, Bradford. "The Accuracy of Teachers' Self-Reports on their Postsecondary Education." *1993 Proceedings of the Section on Survey Research Methods*, Volume II, American Statistical Association.

[2] Credits that were recorded using the quarter system were converted to semester credits. For much of this analysis, teachers are classified according to whether they took more than 40 credits in science, or they took 40 credits or less; this level was chosen as roughly corresponding to whether teachers had majored in science.

The distinction between "advanced" and "limited" coursework in mathematics allows four characterizations of the teachers surveyed:[3]

Coursework in Subject Area	**Coursework in Mathematics Education**	
	Yes	No
Advanced	I	II
Limited	III	IV

One would hypothesize that teachers in Category I (i.e., those who took advanced coursework in mathematics and also took courses in mathematics education) would be the best prepared, and teachers in Category IV the least prepared. Teachers in Categories II and III would fall somewhere in the middle, depending on the relative importance of coursework in the subject area versus coursework in education.[4]

Typically, students were taught by teachers who have had college-level instruction both in science (or mathematics) and in science (or mathematics) education (Figure 1).

- In science, 61 percent of science students had teachers with courses both in science and science education, 38 percent with at least some college science coursework but no courses in science education, and only 2 percent with no course work in science, or course work in science education only. Roughly half (48 percent) of the students had teachers with more than 40 credits combined across both science and science education.
- In mathematics, a somewhat higher percentage of students had teachers with courses both in mathematics and in mathematics education (66 percent, compared with 61 percent in science). However, there were also higher percentages of students whose teachers had taken courses neither in mathematics nor mathematics education (5 percent), or had taken courses only in mathematics education (5 percent, compared with 2 percent for both groups combined in science). Roughly two-thirds (68 percent) of the students had

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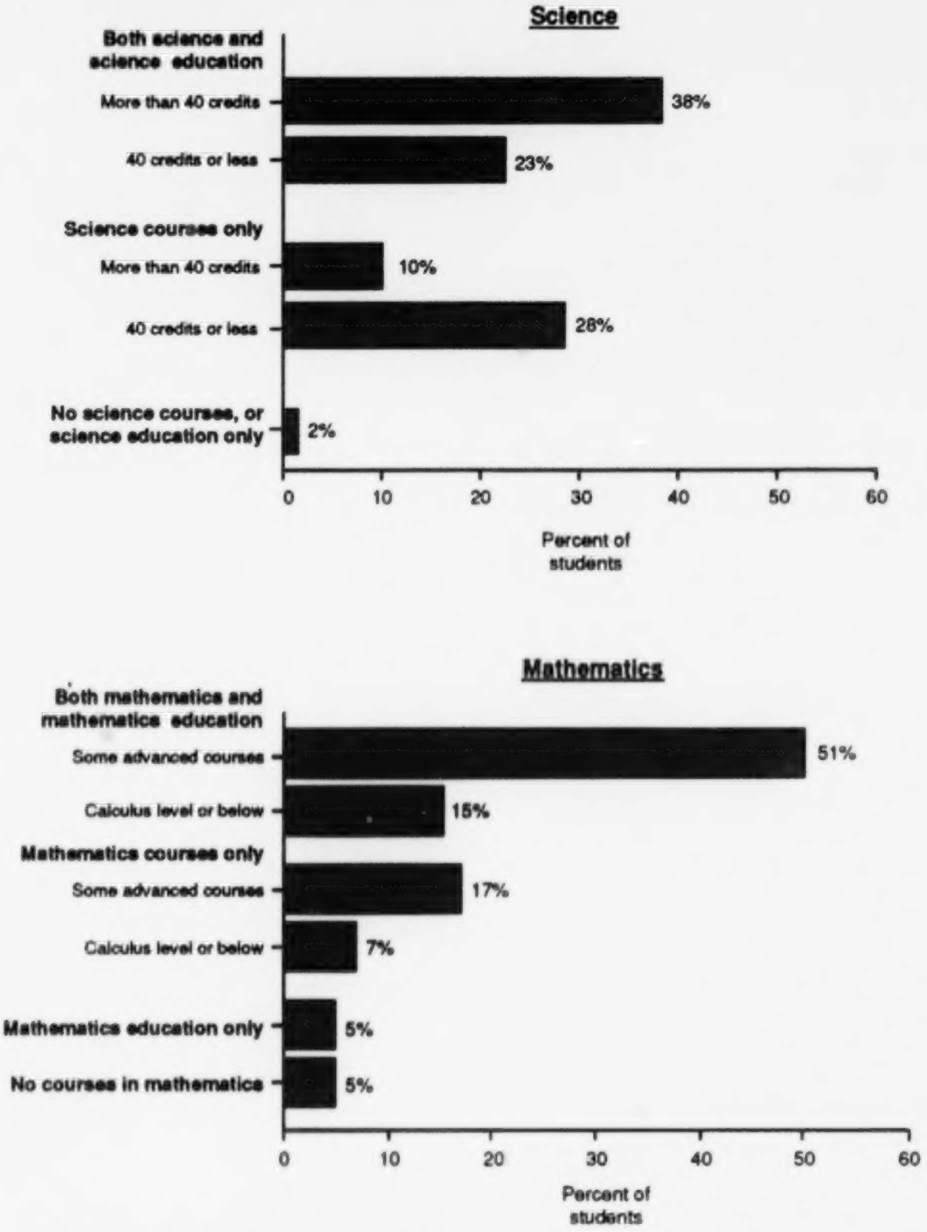
[3] A similar rule applies to science teachers, except that more categories are used to separate advanced and limited coursework.

[4] When the data are presented, several cases will appear where a relationship is inconsistent with this model. That is, Categories II and III sometimes produce results outside of the expected range based on categories I and IV. This report will assume that such inconsistencies are due to random variation or to complexities not captured in this simple model, rather than trying to explain the results. However, if these inconsistencies persist in later analysis, more complex models should be examined.

Figure 1. **Academic preparation of science and mathematics teachers of eighth-grade students, by percentage of students in their classes**



NOTE: Percentages may not add to 100 due to rounding.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis.

teachers who had taken at least some courses in advanced mathematics.[5]

As a variant on the above measure of teachers' background in science, another possibility is to look at teachers' subject area training *within* science. That is, since eighth-grade science typically is devoted to the earth and physical sciences, teachers' training in the life sciences may not necessarily be appropriate. A general measure based upon all science courses could easily overstate a teacher's preparation, perhaps to the point of including a teacher among the category of the best trained teachers even though that teacher may have no background in the area he or she is teaching. In fact, while 47 percent of all students had science teachers who took more than 40 credits of science, only one-fourth of those (24 percent) had teachers with that concentration within the earth and physical sciences, while half (50 percent) had teachers with 20.1 to 40 credits in the earth and physical sciences, and the remainder (26 percent) had teachers with 20 credits or less (Table 24).

Table 24. Teachers' background in the earth and physical sciences relative to their background in all science

Credits in earth and physical science	Credits in all science (Percentage of students)			
	Up to 5	5.1-20	20.1-40	More than 40
Total	6	23	24	47
Total	100	100	100	100
No earth and physical sciences	81	24	2	0
Up to 5 credits	19	28	12	1
5.1-20 credits	0	48	65	25
20.1-40 credits	0	0	21	50
Over 40 credits	0	0	0	24

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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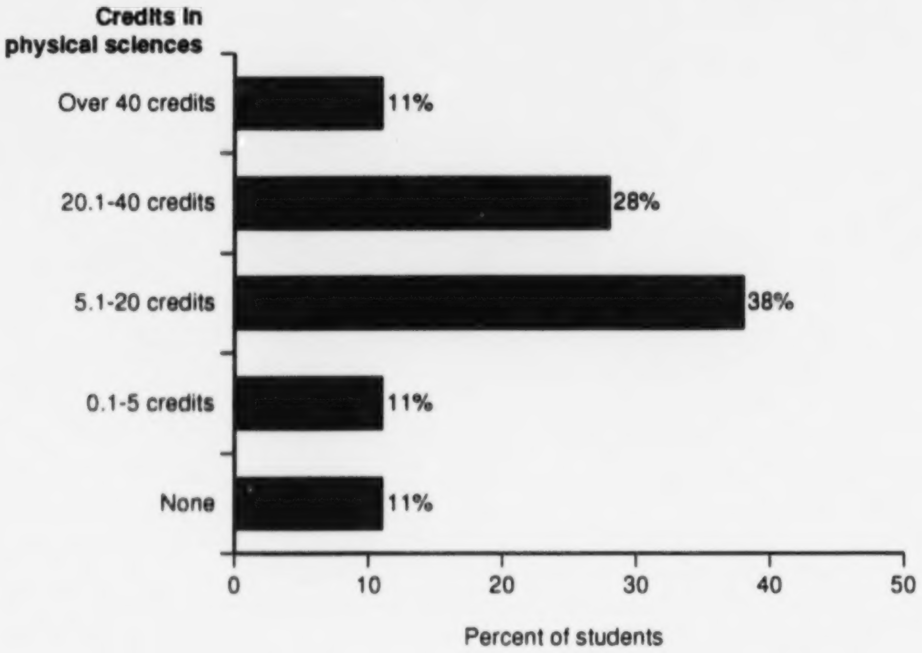
[5] It is difficult to compare these percentages with those in science because of the different methods used for defining advanced preparation.

Figure 2 shows the distribution of students if teachers' backgrounds in the earth and physical sciences is examined. By this measure, teachers were much less well prepared than might be inferred from Figure 1, with students most commonly having teachers with 5.1 to 20 credits of earth and physical sciences.

Figure 2. Academic preparation in earth and physical science teachers of eighth-grade students, by percentage of students in their classes



NOTE: Percentages do not add to 100 due to rounding.

SOURCE: NSF/NELS: 88 Teacher Transcript Analysis.

Because of the relatively small number of students in classes whose teachers had taken no science or mathematics courses, and the even smaller number of sampled teachers on whom those statistics are based, this report will focus on teachers who had taken some science or mathematics courses. Tables at the end of this report provide statistics for all categories of teachers, but readers are cautioned that statistics concerning teachers with no science or mathematics courses in their backgrounds are subject to greater standard errors than other statistics.[6]

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[6] The statistics are more stable for mathematics than for science because a greater proportion of mathematics teachers fall in the category of having completed no subject area coursework, and because the sample of mathematics teachers was larger than that of science teachers.

2.2 Grade Point Averages in Science or Mathematics

It is possible that a teacher could take a small number of required courses in science or mathematics, while performing poorly and never acquiring a high level of proficiency in the subject area. To allow for this possibility, a second measure of teachers' academic preparation was also created, based on teachers' grade point averages within science or mathematics.[7] This measure differs from the previously described measure in providing a measure of the teacher's "success" within the subject area, independent of the number or level of the courses taken.[8]

Most commonly, students had science teachers who received a grade point average in the "B" range (between 2.6 and 3.5; 50 percent of the students), while 35 percent had teachers who received averages in the "C" range (between 1.6 and 2.5), 12 percent in the "A" range (3.6 or higher), and 3 percent an average of "D" or below (1.5 or below; Figure 3). Students' mathematics teachers had a similar distribution: 49 percent of students had teachers with mathematics GPAs between 2.6 and 3.5, though mathematics students were somewhat more likely than science students to have teachers with an average of 3.6 or higher (19 percent), and less likely to have teachers with an average between 1.6 and 2.5 (27 percent).[9]

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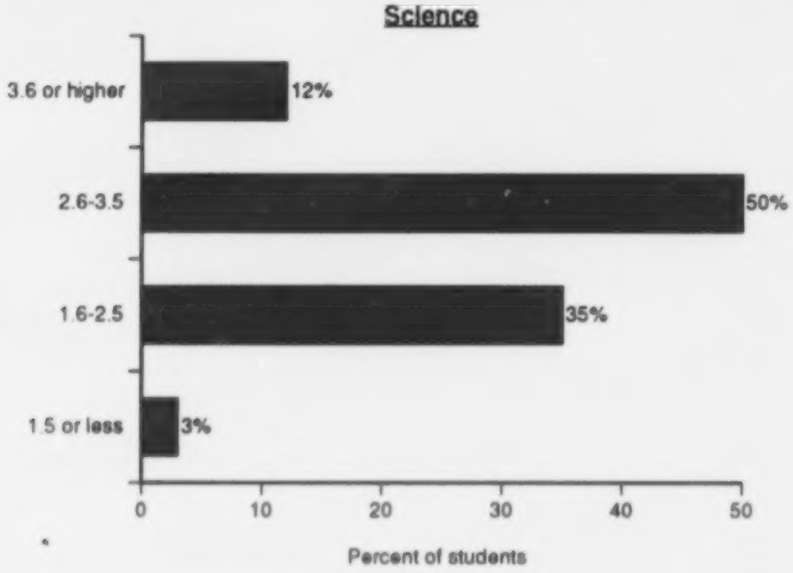
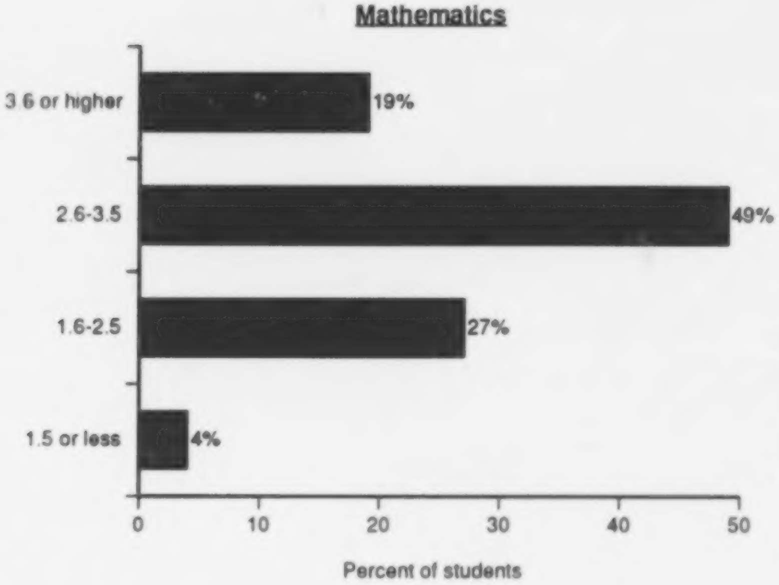
[7] Only courses within the subject area were included when calculating the grade point averages, while courses in science or mathematics education were excluded. Teachers who took no courses in science or mathematics were excluded from this measure, but statistics on these teachers can be found in the measure based on the types of courses taken. Grade point averages were calculated on a four-point scale ("A"=4.0, and "F"=0.0), with pluses and minuses accounted for through an increment of 0.3 (e.g., "B+"=3.3).

[8] Obviously, courses differ in academic difficulty, and the same course may have differing levels of difficulty at different institutions. Nevertheless, grade point averages provide a useful summary measure of a student's success in college. Separate analyses were performed to examine the usefulness of a combined measure based on both grade point averages and the number and types of courses taken; the analyses showed that grade point averages could meaningfully be used as an additional subcategory within each group of types of courses taken, with sometimes substantial differences appearing based on the grade point average. For simplicity, grade point averages are treated separately rather than in combination with the other measure of teachers' academic backgrounds.

[9] Later references to teachers' grade point averages in this report will use a slightly different set of categories (2.5 or lower, 2.5001-3.0, and higher than 3.0) in order to have a more equal distribution among the categories.

Figure 3. Grade point averages of science and mathematics teachers of eighth-grade students in their subject areas, by percentage of students in their classes





NOTE: Percentages may not add to 100 due to rounding. Teachers who did not take courses in the subject area are excluded. GPAs are based on a 4-point scale, with "A" = 4.0.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis.

3. Teachers' Backgrounds and the Classroom Environment

This chapter will examine how the differences found in teachers' academic backgrounds might be related to what happens in the classroom. Teachers' backgrounds may affect the content of their teaching through their use of instructional materials (e.g., is the teacher able to go beyond the information provided in the textbook?), or through their choice of topics (e.g., will teachers emphasize simpler topics if they have weaker academic backgrounds?). Less directly, teachers' academic backgrounds may affect teachers' allocation of time in the classroom, such as their ability or willingness to use labs within science courses. Teachers' backgrounds may also affect their attitudes toward science and mathematics: if a teacher feels well prepared and comfortable with an instructional area, his or her own attitude may affect student attitudes toward the material. Finally, teachers' backgrounds may affect the nature of teacher-student interactions, such as if they are related to teachers' skills in handling students (one goal of teacher education programs) or if they increase teachers' credibility with the students.

3.1 Content Covered by Teachers

One might expect that it is in the content covered by teachers that teachers' academic preparation in science and mathematics might be most important, while the techniques used by teachers might be influenced as much or more by teachers' personalities, their colleagues, the school, and training in teacher education. This section will examine two areas where NELS provides data on the content covered by science and mathematics teachers: in their use of instructional materials, and in their choice of major topics to emphasize.

Instructional Materials

Little difference was found among teachers in their use of instructional materials based on the types of courses they had taken (Table 25). In mathematics, the percentage of students in classes where the textbook was used frequently varied only from 94 to 97 percent. In science, the differences were somewhat larger, but still not sizable. Students of teachers with 40 or fewer credits in science were somewhat more likely to be in classes where the textbook was used frequently (89 to 92 percent) than students of teachers with more than 40 credits (83 percent).

Table 25. Percentage of students in eighth-grade mathematics and science classes where various instructional materials were used frequently, by teachers' educational background

Teachers' background	Instructional materials			
	Textbooks	Other reading materials	Audio-visual materials	Other instructional materials
Mathematics				
Types of courses taken				
Total	95	6	13	9
No courses in mathematics*	96	7	2	13
Courses in mathematics education only*	86	13	30	27
Courses in mathematics but not in mathematics education				
Calculus level or below	94	10	12	11
Some advanced courses	97	3	13	7
Courses in both mathematics and mathematics education				
Calculus level or below	96	5	14	7
Some advanced courses	95	6	12	8
Grade point average in mathematics				
2.5 or lower	93	7	13	12
2.5001 - 3.0	97	6	15	5
Higher than 3.0	96	5	12	6
Science				
Types of courses taken				
Total	86	12	21	14
No science courses, or science education only*	64	40	3	37
Science courses only				
40 credits or less	89	7	19	13
More than 40 credits	83	17	21	23
Both science courses and science education				
40 credits or less	92	9	24	11
More than 40 credits	83	14	21	12
Grade point average in science				
2.5 or lower	87	12	22	12
2.5001 - 3.0	90	10	23	9
Higher than 3.0	83	13	19	19

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.
NOTE: Percentages do not add to 100 because teachers may use more than one type of instructional method frequently .
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

The variations were larger, but not entirely consistent, when comparing teachers based on their grade point averages in mathematics or science. In mathematics, students whose teachers had GPAs of 2.5 or lower were more likely to have other instructional materials used frequently (12 percent) than students whose teachers had higher GPAs (5-6 percent); however, in science, it was the students whose teachers had the highest GPAs who were the most likely to have other instructional materials used frequently (19 percent versus 9-12 percent).

Choice of Major Topics

NELS also asked teachers which of several listed areas were treated as major topics in their classes. The largest differences, based upon the types of courses taken among teachers, were for the topics of algebra and probability/statistics (Table 26). Students whose teachers had taken mathematics but not mathematics education were more likely to see algebra treated as a major topic if their teachers had taken advanced courses (67 percent) than if their teachers had taken courses only at the calculus level or below (54 percent). Differences were smaller among teachers who had taken both mathematics and mathematics education (66 percent versus 64 percent); still, they might be consistent with the hypothesis that a background of *either* advanced courses or mathematics education is related to an increased emphasis on algebra, with no additive effect if both are taken. The differences for probability and statistics are less easily interpreted. Advanced teacher training was related to an *increased* emphasis on probability and statistics among students having teachers with no courses in mathematics education (26 percent versus 9 percent), but a *decreased* emphasis among students whose teachers had taken both mathematics and mathematics education (15 percent versus 25 percent). Given the lack of a systematic pattern, it is difficult to attribute the differences to differences in academic preparation. A similar type of inconsistency appeared with common fractions.

When teachers were compared by their grade point averages, the variations were sometimes more consistent. There was a strong difference among teachers who treated algebra as a major topic, with 71 percent of students in classes where it was a major topic if their teachers had GPAs of 3.0, and only 59 percent if their teachers had GPAs of 2.5 or lower. There also were consistent but smaller differences in other areas: students with teachers having high GPAs were less likely to receive major emphasis on common fractions (58 percent versus 63 percent) and decimal fractions (56 percent versus 62 percent), and more likely to receive emphasis on geometry (56 percent versus 46 percent). Only small differences appeared in the emphasis on probability and statistics (a range of 18 to 19 percent), further reinforcing the likelihood that the inconsistent differences that were found based on the types of courses taken were not important.

Table 26. Percentage of students in eighth-grade mathematics classes where various areas within mathematics were treated as major topics, by teachers' educational background

Teachers' background	Major topic in mathematics classes									
	Common fractions	Decimal fractions	Ratios and proportions	Percentages	Measurement	Geometry	Algebra	Integers	Probability/ statistics	Problem solving
Total	61	58	63	75	35	52	65	73	19	75
Types of courses taken										
No courses in mathematics*	69	58	77	81	25	61	57	73	26	59
Courses in mathematics education only*.	57	46	57	71	35	58	62	73	27	78
Courses in mathematics but not in mathematics education										
Calculus level or below.	59	65	68	78	37	40	54	64	9	72
Some advanced courses	67	62	65	74	36	45	67	73	26	71
Courses in both mathematics and mathematics education										
Calculus level or below.	63	62	65	81	43	54	64	73	25	75
Some advanced courses	57	55	61	73	33	54	66	74	15	78
Grade point average in mathematics										
2.5 or lower	63	62	62	76	39	46	59	73	19	76
2.5001 - 3.0	61	60	59	79	30	50	64	71	18	74
Higher than 3.0.	58	56	66	72	36	56	71	75	19	77

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

For science, differences tended to be small or inconsistent in the choice of major topics, so no strong patterns are immediately apparent based on the types of courses taken (Table 27). Some stronger differences appeared based on teachers' GPAs: if students' teachers had high GPAs, then chemistry (49 percent versus 38 percent) and atomic theory (45 percent versus 35 percent) were more likely to be treated as major topics than for students whose teachers had low GPAs, while plants, animals, human biology, and environmental science were less likely to be treated as major topics.

Table 27. Percentage of students in eighth-grade science classes where various areas within science were treated as major topics, by teachers' educational background

Major topic in science classes	Total	Types of courses taken					Grade point average in science		
		No courses in science, or science education only*	Science courses only		Both science courses and science education				
			40 credits or less	More than 40 credits	40 credits or less	More than 40 credits	2.5 or lower	2.5001-3.0	Higher than 3.0
Plants	12	0	14	4	7	16	15	12	9
Animals	16	25	17	8	15	18	19	17	11
Human biology	19	31	22	17	19	18	23	17	17
Genetics	8	0	8	4	7	10	7	7	10
Personal health	11	25	10	4	16	10	9	14	11
Earth science	57	83	56	57	62	55	58	54	59
Weather	43	57	43	51	45	40	48	37	43
Astronomy	48	25	51	48	53	45	51	43	51
Electricity	29	62	26	31	25	32	31	24	30
Mechanics	22	17	18	26	20	25	22	23	21
Heat	27	14	27	28	25	30	29	26	28
Optics	17	11	15	25	12	19	17	16	18
Chemistry	42	48	36	47	42	44	38	39	49
Atomic theory	39	48	33	42	35	44	35	38	45
Environmental science	31	60	31	29	31	32	37	27	28
Oceanography	34	25	35	43	37	28	38	30	33
Science/society	19	42	17	17	23	19	19	13	24

*Estimates in this category are unstable because of the small number of teachers with no courses in science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

3.2 Teachers' Approach to Homework

The literature review shows that the amount of time students devote to homework is related to student outcomes, though NELS showed fewer hours being devoted to homework than some other studies (perhaps because of the NELS:88 focus on the eighth grade). It is not automatically clear whether teachers' academic background should be associated with homework assignments, but one might speculate that training in teacher education might influence teachers in their use of homework, or that teachers' own background and familiarity with science and mathematics might somehow affect their expectations of the students.

The NELS data provide partial and sometimes inconsistent evidence that teacher training is related to the amount of homework assigned (Table 28). In science, students whose teachers had the highest GPAs in science were the most likely to have more than 2 hours of homework assigned per week (32 percent versus 26 percent for other students). However, the results were less consistent with respect to the content that teachers studied. Among those students whose teachers had taken science but not science education, students were more likely to receive more than 2 hours of homework if their teachers had taken more than 40 credits in science (27 percent versus 20 percent), but when teachers had taken both science courses and science education, students were actually more likely to get 1 hour or less of homework if their teachers had taken more than 40 credits (32 percent versus 25 percent). In mathematics, there was a large difference between students whose teachers had taken advanced courses and those whose teachers had taken courses only at the calculus level or below, but only for teachers who took courses in mathematics but not mathematics education. Sixty percent of students in classes where teachers took advanced classes received more than 2 hours of homework, while only 50 percent of students in classes where teachers took only calculus or below were assigned that much homework. If the teachers took mathematics education courses, then there was no difference based on teachers' background in mathematics, and relatively fewer students received 2 hours of homework than if their teachers had not taken mathematics education (41-42 percent versus 50-60 percent). The differences in homework assignments based on teachers' GPAs in mathematics were inconsistent.

There were also other occasional differences related to teachers' use of homework. In science, students were more likely to have teachers who always kept records of who turned in the homework if their teachers had taken more than 40 credits, whether the teachers took science courses only (91 percent versus 77 percent if the teacher took 40 or fewer credits) or the teachers took both science courses and science education (82 percent versus 74 percent). To a lesser degree, the same types of students were likely to always have their homework returned with grades or corrections (62 percent versus 53 percent if their teachers took science courses only, and 61 percent versus 57 percent if their teachers took both science courses and science education). There also were difference based on teachers' GPAs in science, with students more likely to always get the homework assignment discussed in class if their teachers had science GPAs above 2.5 (64-65 percent versus 53 percent), and somewhat less likely for their teachers to always return their homework with grades or corrections if their teachers had GPAs above 3.0 (54 percent versus 60 percent if the teachers had GPAs of 2.5 or lower). The relationships in mathematics were generally smaller or inconsistent.

Table 28. Teachers' background and their relation to homework assignments

Teachers' background	Amount of homework assigned per week			Keeps records of who turned in homework all of the time	Returns homework with grades or corrections all of the time	Discusses homework assignments in class all of the time
	1 hour or less	Up to 2 hours	More than 2 hours			
Mathematics						
Total	14	41	45	76	47	79
Types of courses taken						
No courses in mathematics*	17	46	37	77	41	74
Courses in mathematics education only*	14	43	43	76	64	71
Courses in mathematics but not in mathematics education						
Calculus level or below	10	39	50	75	44	83
Some advanced courses	8	32	60	78	41	82
Courses in both mathematics and mathematics education						
Calculus level or below	15	43	42	79	58	74
Some advanced courses	16	43	41	74	44	81
Grade point average in mathematics						
2.5 or lower	19	32	49	79	45	77
2.5001 - 3.0	14	45	41	75	43	82
Higher than 3.0	11	43	46	75	50	81
Science						
Total	30	45	25	80	58	60
Types of courses taken						
No science courses, or science education only*	16	42	42	88	51	55
Science courses only						
40 credits or less	34	46	20	77	53	57
More than 40 credits	26	47	27	91	62	64
Both science courses and science education						
40 credits or less	25	47	28	74	57	64
More than 40 credits	32	43	25	82	61	58
Grade point average in science						
2.5 or lower	31	44	26	80	60	53
2.5001 - 3.0	30	44	26	77	58	64
Higher than 3.0	30	48	32	82	54	65

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

In sum, the general direction of these findings is that teachers were somewhat more likely to place a strong emphasis on homework if the teachers had a strong background in the subject area.

3.3 Teachers' Use of Time

Little difference was found among teachers in their use of time based on the types of courses they had taken (Table 29). An exception was in the amount of time devoted to lab periods relative to whole class instruction, but here the results were inconsistent. Students whose science teachers had taken courses in science but not in science education tended to have more time devoted to lab periods and less in whole class instruction if their teachers received more than 40 credits of science instruction. That is, 33 percent (versus 15 percent) were in classes with 2 or more hours of lab periods, and 68 percent (versus 83 percent) received 2 or more hours of instruction directed to the whole class.[1] However, the results were quite different for students whose teachers who had taken courses both in science and science education; among that group, students were *less* likely to have 2 or more hours of lab periods when they had teachers with more than 40 credits. Thus, it is difficult to generalize about the effect of teachers' backgrounds on their use of time.

The differences based on teachers' GPAs were sometimes smaller, but more consistent. If students had teachers with high GPAs, they were more likely than those whose teachers had low GPAs to receive 2 or more hours of instruction in mathematics as a whole class (82 percent versus 77 percent), and less likely to receive individual instruction (13 percent versus 21 percent). In science, the students whose teachers had high GPAs were less likely than others to receive 2 or more hours of lab periods (17 percent versus 22-24 percent).

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[1] These categories were not mutually exclusive, and some students did appear in both categories.

Table 29. Percentage of students in eighth-grade mathematics and science classes where teachers spent 2 or more hours per week in various activities by teachers' educational background

Teachers' background	Two or more hours of instruction devoted to						
	Whole class	Small groups	Individual instruction	Maintaining order/ discipline	Administering test and quizzes	Administrative tasks	Conducting lab periods
Mathematics							
Total	81	10	17	5	3	0	1
Types of courses taken							
No courses in mathematics*	81	12	20	6	8	1	1
Courses in mathematics education only*	83	23	22	6	5	1	6
Courses in mathematics but not in mathematics education							
Calculus level or below	80	7	12	6	0	3	0
Some advanced courses	81	8	12	4	2	0	2
Courses in both mathematics and mathematics education							
Calculus level or below	80	15	28	2	3	1	4
Some advanced courses	81	7	15	5	3	0	1
Grade point average in mathematics							
2.5 or lower	77	13	21	7	5	1	2
2.5001-3.0	84	7	18	4	3	0	1
Higher than 3.0	82	9	13	3	1	0	2
Science							
Total	76	9	8	6	4	1	21
Types of courses taken							
No science courses, or science education only*	54	8	6	0	8	0	14
Science courses only							
40 credits or less	83	8	8	7	6	1	15
More than 40 credits	68	3	4	3	1	0	33
Both science courses and science education							
40 credits or less	77	15	9	8	6	2	27
More than 40 credits	72	9	8	4	1	0	20
Grade point average in science							
2.5 or lower	74	11	11	8	6	2	22
2.5001 - 3.0	78	9	6	5	3	0	24
Higher than 3.0	76	8	7	3	1	0	17

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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3.4 Teachers' Attitudes

One area where some of the clearest differences appeared based on the types of courses taken was in teachers' feelings of preparedness for teaching science or mathematics (Table 30). When teachers had taken advanced classes in mathematics and courses in mathematics education, 91 percent of students were in classes where the teacher felt very well prepared. But when teachers either had not taken advanced courses in mathematics or had not taken courses in mathematics education, only 75 to 80 percent of students had teachers who felt very well prepared. Also, unlike many of the previous findings where teacher's grade point averages were more likely to provide consistent differences than the types of courses taken, for teacher preparedness in mathematics the important differences were based entirely on the types of courses taken: the range based on GPA varied only from 84 to 88 percent.

For science, a smaller percentage of teachers felt very well prepared than in mathematics (53 percent versus 83 percent). While no differences appeared based on whether teachers had taken science education courses, there were strong differences based on the number of credits in science that teachers had taken. Two-thirds of students had teachers who felt very well prepared if the teachers had taken more than 40 credits in science, compared with one-third of students with teachers having 40 credits or fewer.

3.5 Patterns in Teacher and Student Assignments

As stated earlier, one of the major difficulties in relating teacher backgrounds to student outcomes is the possibility that there were disparities in teacher and student assignments, so that the best students were given the best prepared teachers. To the extent that such a pattern occurred and that appropriate statistical controls are not used, a researcher might include that differences in teachers' backgrounds were important when the relationship was entirely due to these differences in assignments. Further, if teachers' backgrounds are found to be important, disparities in teacher assignments have important implications concerning the equity of the educational system, with some classes of students receiving poorer teachers than others.

There are many reasons why disparities may have appeared in teacher assignments. Some might be due to teacher self-selection or teacher availability, so that, for example, the characteristics of teachers available to urban schools may have been different from those of teachers available to suburban or rural schools. Others may have resulted from student or parent choices, if some students or their parents sought schools or classes with particular

Table 30. Percentage of eighth-grade students in mathematics and science classes whose teachers felt well prepared to teach the courses, by teachers' educational background

Teachers' background	Teachers' feelings of preparedness				
	Very well prepared	Well prepared	Adequately prepared	Somewhat prepared	Totally unprepared
Mathematics					
Total	83	13	3	1	0
Types of courses taken					
No courses in mathematics*	59	31	9	1	0
Courses in mathematics education only*	71	23	3	1	1
Courses in mathematics but not in mathematics education					
Calculus level or below	76	17	1	5	0
Some advanced courses	80	15	5	0	0
Courses in both mathematics and mathematics education					
Calculus level or below	75	18	6	0	0
Some advanced courses	91	7	1	0	0
Grade point average in mathematics					
2.5 or lower	84	12	3	1	0
2.5001 - 3.0	88	11	1	0	0
Higher than 3.0	85	11	4	0	0
Science					
Total	53	30	13	4	0
Types of courses taken					
No science courses, or science education only*	48	25	0	27	0
Science courses only					
40 credits or less	37	33	23	6	1
More than 40 credits	68	17	11	4	0
Both science courses and science education					
40 credits or less	38	46	12	4	0
More than 40 credits	69	22	8	1	0
Grade point average in science					
2.5 or lower	48	28	18	4	1
2.5001 - 3.0	59	30	8	3	0
Higher than 3.0	53	32	13	3	0

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.
NOTE: Percentages may not add to 100 due to rounding.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

characteristics. Schools also may have had policies such as placing high-achieving students together, and perhaps assigning the best teachers to those classes. This could be especially likely to happen in mathematics, where some students would be taking algebra in the eighth-grade, and others would not; if the teachers assigned to teach algebra had stronger backgrounds than those assigned to teach other eighth-grade courses, the strongest students could easily end up with the best prepared teachers. Yet while such policies might appear logical, they create the risk that some groups of students are doubly disadvantaged: the students not only start out at lower levels of academic proficiency but they may be given fewer or less adequate resources for overcoming this disadvantage.

Table 31 provides confirmation of disparities in teacher assignments. For those teachers who had the least preparation in mathematics -- mathematics courses only at the calculus level or below, with no courses in mathematics education -- students were disproportionately likely to be attending schools where more than 60 percent of students were minorities (24 percent versus 14 percent among the other three groups), to be attending urban schools (42 percent versus 20-23 percent), and to be black or Hispanic (34 percent versus 21-23 percent). By contrast, those teachers whose backgrounds were the strongest (with both advanced mathematics courses and mathematics education) were disproportionately likely to describe the overall achievement levels of students in the sampled classes as higher than the average eighth grade student in their schools (31 percent of their students versus 19-26 percent for other teachers). Similarly, teachers with GPAs above 3.0 had a greater concentration of students in such classes (33 percent) than other teachers (23 percent).

In science, the differences were not as large or as consistent in terms of the types and number of courses that teachers had taken. More substantial differences sometimes appeared based on teachers' grade point averages. Students whose teachers had GPAs above 3.0 were more likely than students whose teachers had GPAs of 2.5 or lower to be in urban (25 versus 20 percent) or rural (40 percent versus 35 percent) schools, and less likely to be at schools with more than 60 percent minority students (8 percent versus 15 percent) or in classes with average achievement levels (31 percent versus 40 percent).

3.6 Influence of Teachers on Student Attitudes

One of the particular reasons why the eighth grade has been discussed as an important time period for researchers to study is that the eighth grade may be a time when students are deciding whether to pursue science and mathematics in their future education and careers. A teacher might not only be able to affect a student's learning in the particular subject matter covered in the eighth grade, but might also potentially affect a student's future. Most likely, a teacher's influence would be strongest on a student's

Table 31. The percentage of eighth-grade science and mathematics students with various characteristics, by quality of teacher's academic preparation in the subject area

Teacher's academic background	School characteristics					Class achievement levels				Student characteristics			
	More than 60% are minorities	More than half receive free lunch	Urbanicity			High	Average	Low	Widely differing	Black or Hispanic	Low SES quartile	Female	5.5 hours or more of homework per week
			Urban	Suburban	Rural								
Mathematics teachers, total. .	16	14	25	42	33	27	38	20	15	24	25	50	33
Types of courses taken													
No mathematics courses* . .	41	23	33	49	18	20	39	27	13	44	28	51	31
Mathematics education only*.	19	21	48	35	16	22	28	26	25	28	29	49	30
Mathematics only													
Calculus level or below . .	24	19	42	29	29	19	37	24	19	34	23	52	35
Some advanced courses . .	14	14	23	49	28	26	42	23	10	23	24	49	33
Both mathematics and mathematics education													
Calculus level or below . .	14	11	20	43	38	19	43	22	16	23	28	50	33
Some advanced courses . .	14	12	22	41	36	31	36	17	15	21	24	50	33
Grade point average in mathematics													
2.5 or lower.	18	13	29	41	31	23	34	23	20	27	27	49	31
2.5001-3.0	17	16	21	35	43	23	40	19	18	23	28	49	32
Higher than 3.0	12	11	23	47	30	33	41	17	9	22	20	52	34
Science teachers, total	12	13	23	44	33	23	37	16	23	20	24	51	32
Types of courses taken													
No science courses, or science education only*	23	11	27	42	31	22	49	16	14	39	27	49	28
Science only													
40 credits or less.	13	12	19	38	42	25	35	13	26	18	27	49	33
More than 40 credits . . .	13	9	28	52	20	22	29	17	32	25	22	49	37
Both science and science education													
40 credits or less.	11	16	23	49	28	25	37	19	18	22	24	53	34
More than 40 credits . . .	10	12	22	44	34	21	40	16	23	17	23	51	31
Grade point average in mathematics													
2.5 or lower.	15	16	20	45	35	23	40	18	19	23	27	50	31
2.5001-3.0	11	13	22	53	25	21	39	15	25	19	24	51	32
Higher than 3.0	8	10	25	34	40	26	31	15	28	14	21	52	36

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

attitudes towards the subjects being taught, but there is at least anecdotal evidence of individual teachers who affect students in a much broader way, including their attitudes toward life and their plans for the future.

To the extent that teachers do exert such influence, a variety of teacher characteristics might be important, including a teacher's personality, the time spent with the student outside of the classroom, and the teacher's race and gender. With regard to a teacher's academic background, one might speculate that a teacher's content knowledge of the subject matter could affect the teacher's ability to motivate the student (e.g., by making the subject appear interesting, relevant, or comprehensible), and that a teacher's background in teacher education might affect the nature of the teacher's interactions with the student. This section will look at three general areas in which a student's attitudes might be affected: the student's general attitudes, the student's attitudes more specifically towards science or mathematics, and the student's future education and career plans.

Table 32 examines the relationship of teachers' backgrounds with three of the general student attitudes that were earlier shown to be related to student achievement on the NELS cognitive test scores: students' agreement or disagreement with the statements, *"I don't have enough control over the direction my life is taking"*; *"In my life, good luck is more important than hard work for success"*; and *"I am able to do things as well as most other people."* For each of these three measures, the differences based on teachers' backgrounds were small and inconsistent. For example, while a very slightly higher percentage of students felt they were able to do things as well as others if their teachers had taken advanced calculus courses among those teachers with no background in teacher education, the difference was in the opposite direction among teachers with courses in both mathematics and mathematics education. Thus, teachers' academic backgrounds do not appear important in affecting such general student attitudes; this is not surprising given the large number of influences that students would have been subjected to before and during the students' exposure to the science and mathematics teachers.

One might expect a stronger influence by the teachers on students' attitudes towards science and mathematics, but here again the differences among the students were quite small. Very little variation was found among the students in terms of whether they looked forward to class or whether they felt the subject would be useful in the future. To a small degree, students were less afraid to ask questions in class if their science teachers received a grade point average in science above 2.5 (32 percent strongly disagreed that they were afraid, compared with 28 percent of students whose teachers had GPAs lower than 2.5), but even this small difference did not consistently appear in mathematics.

Table 32. Teachers' background and students attitudes

Teachers' background	General attitudes			Attitudes about subject area			Future plans		
	Don't have enough control over life	Good luck more important than hard work	Able to do things as well as others	Look forward to class	Afraid to ask questions	Subject will be useful in future	Will finish college or beyond	Will enroll in college preparatory program in high school	Expects professional/ business/ managerial career
	Strongly disagree	Strongly agree	Strongly disagree	Agree	Strongly disagree	Strongly agree			
Mathematics									
Total	33	42	40	57	25	44	66	29	28
Types of courses taken									
No courses in mathematics*	30	35	36	53	22	43	67	25	32
Courses in mathematics education only*	33	46	41	57	22	43	67	30	29
Courses in mathematics but not in mathematics education									
Calculus level or below	29	41	39	56	25	42	63	24	26
Some advanced courses	33	41	42	57	27	45	66	34	25
Courses in both mathematics and mathematics education									
Calculus level or below	32	44	42	58	26	45	63	27	27
Some advanced courses	33	43	39	57	26	43	67	30	29
Grade point average in mathematics									
2.5 or lower	33	42	42	58	26	45	62	28	26
2.5001 - 3.0	30	41	37	57	23	42	63	27	26
Higher than 3.0	34	44	40	57	27	43	72	33	31
Science									
Total	33	41	39	62	31	26	64	29	29
Types of courses taken									
No science courses, or science education only*	37	44	42	65	35	27	55	23	29
Science courses only									
40 credits or less	33	42	40	66	31	26	64	30	28
More than 40 credits	31	40	36	62	31	27	68	31	30
Both science courses and science education									
40 credits or less	32	40	40	60	30	26	62	29	30
More than 40 credits	32	41	39	60	31	26	65	28	29
Grade point average in science									
2.5 or lower	31	39	39	62	28	25	62	27	28
2.5001 - 3.0	33	41	40	62	32	28	66	28	30
Higher than 3.0	33	43	40	61	32	25	66	34	30

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

It is in the third set of student attitudes -- their plans for the future -- that the strongest and most consistent differences appeared based on teachers' academic backgrounds. Students whose mathematics teachers received a mathematics GPA higher than 3.0 were more likely to plan to finish college or attend graduate school (72 percent versus 62-63 percent), to plan to enroll in a college preparatory or academic program in high school (33 percent versus 27-28 percent), and to expect a professional or managerial career (31 percent versus 26 percent). To a lesser degree, differences could also be found based on the types of mathematics courses the teachers had taken; students whose teachers had taken advanced mathematics courses (i.e., courses beyond the level of calculus) were more likely to plan to enroll in college preparatory programs (30-34 percent) than students whose teachers had taken courses only at the calculus level or below (24-27 percent). In science, the differences were smaller, but students whose teachers had GPAs in science above 3.0 were more likely to plan to enroll in college preparatory programs than other students (34 percent versus 27-28 percent).

Given the small and inconsistent differences that were found among students with relation to their teachers' backgrounds and the students' other attitudes, one might question whether it is reasonable that teachers might affect their students' future educational plans but not the other attitudes. A more likely explanation is that any relationship between teachers' backgrounds and students' future plans was due to patterns in the assignment of students and teachers (with the most academically oriented students receiving the teachers with the strongest academic preparation), and not that the teachers were influencing the students' plans.

4.

Teachers' Backgrounds and Student Outcomes

The preceding findings provide some basis for anticipating that teachers' academic backgrounds might be related to student outcomes. Teachers' grade point averages in science and mathematics sometimes were related to differences in teaching practices, and either teachers' course-taking patterns or their GPAs were related to teachers' feelings of preparedness.

Table 33 provides a preliminary indication that teachers' academic backgrounds can be related to student outcomes.[1] Students whose teachers had taken advanced courses in mathematics performed better than those whose teachers had taken courses only at the calculus level or below. For example, the mean standardized score for students was highest (51.3) for students whose teachers had taken both advanced courses in mathematics and courses in mathematics education. Next highest were students whose teachers had taken advanced courses in mathematics but no courses in mathematics education (50.9), while students whose teachers had taken mathematics courses only at the calculus level or below received mean scores of 48.7 (if the teachers had taken mathematics education courses) and 48.2 (if the teachers had not taken mathematics education courses). Generally, throughout the various measures of student proficiency offered in Table 33, students whose teachers had taken advanced courses in mathematics performed best, while teachers' experience in mathematics education was related to improved student test scores only if the teachers also had taken advanced mathematics courses. The measure of teachers' grade point averages in mathematics also proved useful, with students whose teachers' GPAs were high performing the best: for example, when teachers had a GPA above 3.0, their students had a mean standardized score of 51.9, while teachers with a GPA of 2.5 or lower had students with a mean score of 49.2.

In science, the differences in test scores were smaller than those found for mathematics, and showed only marginally higher test scores for students whose teachers had taken more than 40 credits of science. For example, among teachers with courses in science but not in science education, students received a mean standardized score of 51.2 for teachers with more than 40 credits and 50.4 for teachers with 40 credits or fewer. Similarly, among teachers with courses in both science and science education, students received a mean of 50.5 if teachers had more than 40 credits, and 50.0 if teachers had 40 credits or fewer. No improvement was found in test scores based on teachers' coursework in science education. Again, teachers' GPAs could be related to differences in student outcomes: students whose

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[1] Controls for other student and school characteristics are presented later in this chapter.

Table 33. Mean scores per student in science and mathematics eighth-grade proficiency exams, by teachers' educational background

Teachers' background	Number right	Number wrong	Number not attempted	Formula score	Standardized score	Item response theory		Quartile[1]
						Estimated number right	Formula score	
Mathematics								
Total	21.8	17.3	0.9	16.3	50.3	22.1	16.3	2.5
Types of courses taken								
No courses in mathematics[2]	18.5	19.9	1.6	12.1	46.6	18.9	12.0	2.1
Courses in mathematics education only[2]	20.8	18.6	0.6	14.7	48.9	21.0	14.8	2.4
Courses in mathematics but not in mathematics education								
Calculus level or below	20.1	19.1	0.9	13.9	48.2	20.2	13.9	2.3
Some advanced courses	22.4	16.8	0.8	17.0	50.9	22.6	17.0	2.6
Courses in both mathematics and mathematics education								
Calculus level or below	20.5	18.5	1.1	14.5	48.7	20.7	14.5	2.4
Some advanced courses	22.7	16.5	0.8	17.4	51.3	22.9	17.4	2.6
Grade point average in mathematics								
2.5 or lower	20.9	18.1	0.9	15.1	49.2	21.1	15.1	2.4
2.5001 - 3.0	21.6	17.6	0.9	15.9	49.9	21.7	15.9	2.5
Higher than 3.0	23.3	16.0	0.7	18.1	51.9	23.4	18.1	2.7
Science								
Total	13.5	11.1	0.4	10.1	50.4	13.6	10.1	2.5
Types of courses taken								
No science courses, or science education only[2]	12.2	12.6	0.2	8.4	47.4	12.3	8.4	2.3
Science courses only								
40 credits or less	13.5	11.1	0.4	10.1	50.4	13.6	10.1	2.6
More than 40 credits	13.9	10.7	0.4	10.6	51.2	14.0	10.6	2.6
Both science courses and science education								
40 credits or less	13.4	11.3	0.4	9.9	50.0	13.5	9.9	2.5
More than 40 credits	13.5	11.0	0.5	10.1	50.5	13.6	10.1	2.5
Grade point average in science								
2.5 or lower	13.0	11.6	0.4	9.4	49.2	13.2	9.5	2.4
2.5001 - 3.0	13.7	10.9	0.4	10.4	50.8	13.8	10.4	2.6
Higher than 3.0	14.0	10.6	0.4	10.7	51.4	14.1	10.7	2.7

[1] Quartile ranges from 1 (lowest quartile) to 4 (highest quartile).

[2] Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

teachers had science GPAs above 3.0 received a mean standardized score of 51.4, while students whose teachers had GPAs of 2.5 or lower received a mean of 49.2.

A significant point is that it was not only important whether science teachers had a strong background in science, but despite the relatively simple level of science taught in the eighth grade, it also mattered whether teachers' backgrounds were specifically in the earth and physical sciences. If teachers' backgrounds (in terms of the number of total credits) in *all* of the sciences are considered, there still was a relationship between the number of credits earned and students' cognitive test scores *for those teachers with less than 40 credits of science instruction*, but not for the roughly half of all students whose teachers had taken more than 40 credits (Table 34). The reason may be that not all postsecondary science courses are relevant for eighth-grade science instruction. For example, science teachers often had a strong background in the biological sciences, yet no relationship appeared between teachers' backgrounds in the biological sciences and students cognitive test scores. Students whose teachers had earned more than 40 credits in the biological sciences received much the same test scores (a mean of 50.0) as those whose teachers had earned no credits (49.5). When student scores are compared based on teachers' background in the earth and physical sciences, however, there is a consistent pattern of increasing mean student scores as the number of credits in the earth and physical sciences increased.

Table 34. Percent of students and mean science standardized scores, by type of teachers' background in science

Number of credits	Method for measuring teachers' background					
	All science courses		Life sciences only		Earth and physical sciences only	
	Percent of students	Mean score	Percent of students	Mean score	Percent of students	Mean score
None	3	48.0	12	49.5	11	48.2
0.1-5 credits	2	48.2	12	50.3	11	49.3
5.1-20 credits	23	49.2	39	50.3	38	50.4
20.1-40 credits	24	51.2	26	50.8	28	50.7
Over 40 credits	47	50.6	11	50.0	11	51.8

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Besides overall numeric scores, NELS also provided for grading students based on three proficiency levels in mathematics: able to perform simple arithmetic operations on whole numbers; able to perform simple arithmetic operations with decimals, fractions, and roots; and able to perform simple problem solving requiring conceptual understanding and/or the development of a solution strategy. Each of the proficiency levels was associated with four questions from the larger mathematics test, and to establish proficiency at a level, students had to answer at least three of the four questions correctly for that level as well as showing proficiency at all lower levels.

Figure 4 displays the relationship between teachers' academic backgrounds and student proficiency levels in mathematics. Teachers who had taken advanced courses in mathematics had a greater percentage of students at the highest proficiency level (22 percent) than teachers who had taken courses only at the calculus level or below (13-17 percent). No additional improvement was found in students' proficiency levels if their teachers had also taken courses in mathematics education.

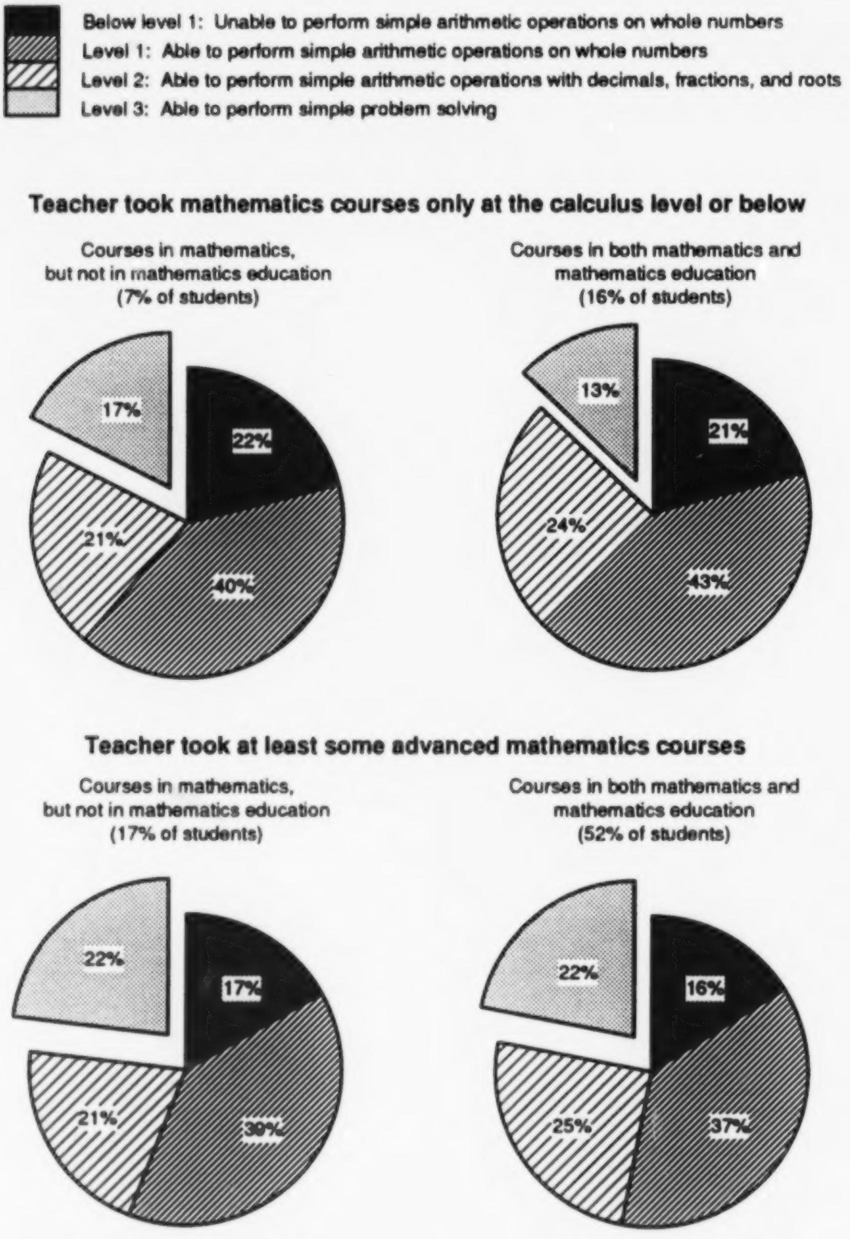
There also was a relationship between teachers' GPA and students' proficiency levels: students whose teachers had mathematics GPAs above 3.0 were more likely to be in the top proficiency level (24 percent) than those with teachers with GPAs of 2.5 or lower (17 percent; Figure 5).

4.1 Inequalities in Teacher Assignments and Student Outcomes

Despite the above findings of a relationship between teachers' academic preparation and student outcomes, it is possible that differences in student outcomes might be explained less by differences among teachers than by some other factor that also happens to be related to teachers' backgrounds. For example, the differences may be due to inequalities in teacher assignments. If the "best" teachers (in terms of academic preparation) were assigned to the "best" students, the apparent relationship between teacher qualifications and student outcomes might be a result of that teacher assignment process, rather than because those teachers are more effective in improving students' academic proficiency. The previous chapter indicated that there are inequalities in teacher assignments, so such inequalities might easily be the explanation for the differences in outcomes.

The differences in teacher assignments, however, were not sufficient to explain the relationship between teachers' academic backgrounds and student outcomes. If one controls for the student-related characteristics, teachers' backgrounds still were related to student outcomes, with students performing better (on average) when their teachers had stronger backgrounds (Table 35). For example, if one limits the sample to classes that the teacher described as having higher than average achievement levels, the mean standardized score for students whose teachers had taken both advanced mathematics courses and courses in mathematics education was 59.4. Among students whose teachers had taken advanced courses in mathematics but no courses in mathematics education, the mean was 58.6, and among students whose teachers had not taken advanced courses in mathematics, it was 57.0. Similarly, teachers' GPAs could generally be related to

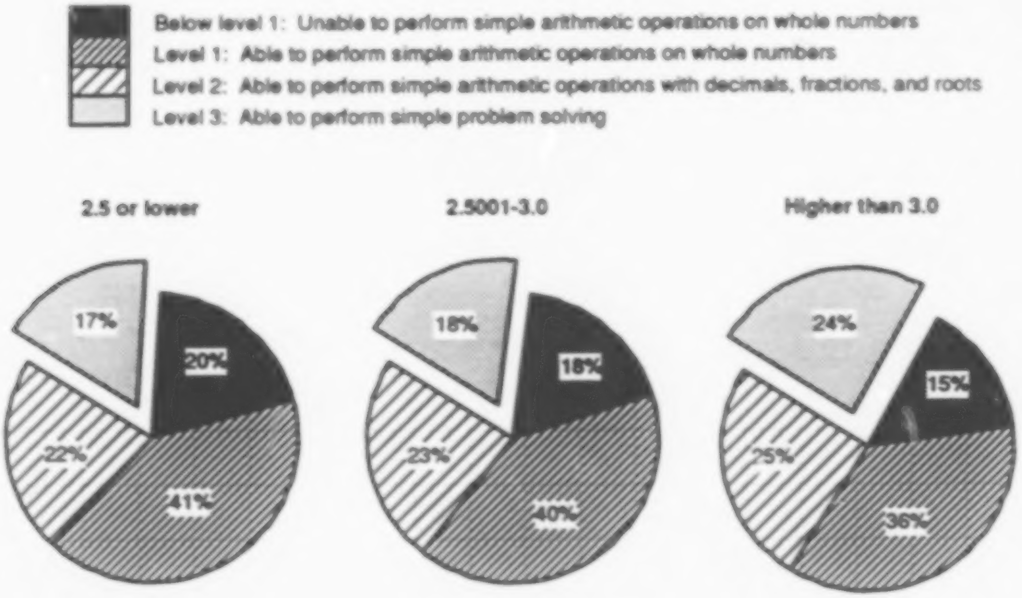
Figure 4. **Proficiency of eighth-grade mathematics students, by teachers' backgrounds in mathematics**



NOTE: Percentages may not add to 100 due to rounding.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis.

Figure 5. **Proficiency of eighth-grade mathematics students, by teachers' grade point average in mathematics**



NOTE: Percentages may not add to 100 due to rounding.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis.

Table 35. Mean scores per student in science and mathematics eighth-grade proficiency exams, by teachers' educational background and student-related characteristics: United States

Teachers academic background	School characteristics					Class achievement levels				Student characteristics			
	More than 60% are minorities	More than half receive free lunch	Urbanicity			High	Average	Low	Widely differing	Black or Hispanic	Low SES quartile	Female	5.5 hours or more of homework per week
			Urban	Suburban	Rural								
Mathematics teachers, total	44.6	44.3	48.2	51.4	50.4	58.5	49.3	43.0	47.8	44.7	44.9	50.0	53.4
Types of courses taken													
No mathematics courses*	43.4	41.3	42.8	47.6	48.6	51.8	47.1	39.6	48.3	43.2	41.9	45.7	48.9
Mathematics education only*	47.4	44.7	49.0	49.4	47.7	57.0	48.5	42.9	48.6	45.8	43.5	48.7	51.6
Mathematics only													
Calculus level or below	43.0	41.5	45.7	49.8	50.5	57.0	47.1	41.2	50.0	44.1	43.5	48.1	50.5
Some advanced courses	46.2	46.7	48.4	51.3	51.9	58.6	50.3	44.3	48.4	45.4	45.9	50.5	54.1
Both mathematics and mathematics education													
Calculus level or below	43.9	44.6	51.5	48.7	47.3	57.0	48.8	43.0	46.3	44.2	43.9	48.0	51.3
Some advanced courses	44.8	44.6	48.5	52.9	51.1	59.4	49.7	43.2	47.6	44.8	45.6	51.2	54.6
Grade point average in mathematics													
2.5 or lower	43.3	42.5	47.3	50.1	49.7	57.7	49.0	43.0	46.9	43.8	44.8	48.8	52.5
2.5001-3.0	43.8	44.1	46.6	51.7	50.1	58.9	49.3	42.5	47.7	44.5	44.6	50.2	52.9
Higher than 3.0	46.5	46.3	50.7	52.7	51.4	59.3	50.0	43.6	49.0	45.8	46.0	51.4	54.8
Science teachers, total	44.8	45.5	49.2	51.2	50.0	55.3	49.7	45.3	50.0	45.1	44.9	49.8	52.9
Types of courses taken													
No science courses, or science education only*	42.9	44.1	49.0	46.6	48.4	53.2	47.3	42.1	47.4	44.1	43.2	46.7	50.6
Science only													
40 credits or less	42.2	46.5	46.8	51.6	50.9	54.8	49.7	44.8	49.7	44.1	45.6	49.9	53.2
More than 40 credits	46.1	43.9	50.2	52.1	50.4	55.6	49.6	48.5	50.9	45.7	42.6	51.1	53.7
Both science and science education													
40 credits or less	45.7	44.7	49.9	51.0	48.5	55.5	49.8	44.9	48.1	45.2	44.6	49.5	52.5
More than 40 credits	46.7	45.7	50.1	51.0	50.0	55.6	49.7	45.3	50.8	45.9	45.3	49.8	52.9
Grade point average in mathematics													
2.5 or lower	43.6	43.4	47.3	50.7	48.4	54.1	49.1	45.6	47.3	44.4	44.3	48.8	51.3
2.5001-3.0	46.3	44.4	48.8	51.3	51.6	55.5	49.7	46.0	51.4	45.6	44.9	50.1	53.7
Higher than 3.0	46.0	51.0	51.5	52.0	50.9	56.5	50.8	44.6	51.1	46.2	46.3	51.0	54.1

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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differences in student outcomes within these subgroups, and sometimes to a larger degree than reported in Table 33. For example, the mean standardized score for all students ranged from 49.2 among students whose teachers had GPAs of 2.5 or lower to 51.9 among students whose teachers had GPAs higher than 3.0, but for students at schools where more than half of the students received free lunches, the range was from 42.5 to 46.3.

Another way to examine the importance of selection bias is to examine the comparison between the earth and physical sciences and the life sciences in Table 34 (on page 65). If content knowledge in the area is important, then one would expect teachers' background in the physical sciences to be more important than their background in the life sciences (as is the case); if specific content knowledge were not important, one might expect to find the same patterns based on teachers' background in the life sciences as in the physical sciences. In fact, Table 36 shows that some of the same selection bias occurs for teachers whose strength is in the life sciences as for teachers in the earth and physical sciences. Teachers with substantial training in *either* the earth and physical sciences or the life sciences were less likely to be at schools where more than 60 percent of the students were minorities, where more than half received free lunches, or to have sampled students who were black or Hispanic. Given these disparities in teacher assignments in the life sciences, but the absence of any relationship between teachers' backgrounds in the life sciences and student outcomes, the relationships that were found for the physical sciences appear to be based on teachers' content knowledge.

4.2 Multiple Regressions

The indications above of possible bias in teacher assignments (with high-achieving students getting the teachers with the strongest academic preparation), along with the extensive list of variables that were shown in Chapter 1 to be related to student achievement, make it clear that a multivariate approach is needed to properly measure the impact of teachers' academic preparation. To perform this analysis, multiple regressions were computed using the variables found to be important in Chapter 1. Variables that were not statistically significant were dropped from the analysis; however, variables were kept in the analysis if they appeared theoretically required (e.g., if they were measures of the teachers' academic backgrounds, or to ensure that every major category of variables included at least one measure).[2]

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[2] For example, while both theory and the preliminary analysis suggest that student attitudes are important, the various measures of student attitudes tend to be correlated and a single measure may be sufficient. Some variables were also added to the regression equation to compensate for missing data (e.g., to measure variation from the mean for students for whom no course grades were available in the subject area), rather than dropping those cases from the analysis and possibly biasing the results. These variables were retained whether or not they were statistically significant. For this analysis, since the major goal was to measure the importance of teachers' academic backgrounds and thus to control for other variables that might be correlated with the teachers' backgrounds, the possible bias resulting from leaving out variables was considered a greater risk than the increased variance resulting from including irrelevant variables.

Table 36. Comparison of student-teacher assignment patterns based on teachers' preparation in earth and physical sciences and in life sciences

Teacher's academic background	School characteristics					Class achievement levels				Student characteristics			
	More than 60% are minorities	More than half receive free lunch	Urbanicity			High	Average	Low	Widely differing	Black or Hispanic	Low SES quartile	Female	5.5 hours or more of homework per week
			Urban	Suburban	Rural								
Science teachers, total	12	13	23	44	33	23	37	16	23	20	24	51	32
Earth and physical sciences													
No earth/physical sciences	25	14	32	40	28	19	41	23	18	31	27	49	30
0.1-5 credits	14	17	21	39	39	25	32	16	27	25	25	50	31
5.1-20 credits	10	14	19	46	35	25	39	15	22	19	26	52	32
20.1-40 credits	9	10	26	41	33	22	36	16	27	17	22	50	34
Over 40 credits	9	10	19	52	29	23	38	17	23	18	20	50	32
Life sciences													
No life sciences	20	21	26	41	34	24	44	18	15	33	25	48	31
0.1-5 credits	13	16	31	48	21	22	38	14	26	23	23	49	36
5.1-20 credits	11	10	19	43	38	23	36	16	26	16	25	51	31
20.1-40 credits	11	12	17	51	32	24	36	15	25	20	22	51	33
Over 40 credits	8	13	35	30	35	22	40	20	19	18	28	55	34

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 37 indicates that, even with extensive controls for student and school characteristics, the academic background of eighth-grade mathematics teachers was related to student achievement on the cognitive test scores. On average, students performed better if their teachers had taken courses beyond the level of calculus, and the measure was statistically significant. However, measures of the impact of courses in mathematics education were relatively small and statistically insignificant. Measures of the impact of high grade point averages in mathematics also failed to be statistically significant.[3]

Similar results appeared for science (Table 38). On average, students performed better if their teachers had taken a large number of credits in the earth and physical sciences, and the measure was statistically significant. Again, however, courses in science education did not have a statistically significant impact. Also as in mathematics, the coefficient for teachers' grade point averages in science was positive but statistically insignificant.

Table 39 is included to provide additional confirmation of the importance of measuring eighth-grade science teachers' backgrounds in the earth and physical sciences, rather than in all of the sciences. While the number of credits in the earth and physical sciences did show a statistically significant impact, the number of credits in all other science courses did not. This finding helps to explain the failure of some general measures (such as whether the teacher earned a degree in one of the sciences) to be related to student achievement in the eighth grade; teachers frequently have an extensive background in the life sciences, but this background is apparently not helpful when teaching the earth and physical sciences.

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[3] Ideally the regression equation would also include a variable to measure the impact of teachers taking mathematics education courses *in combination with* also taking advanced courses in mathematics. However, this variable was not statistically significant, and because of its correlation with the measure of advanced course taking in mathematics, that measure would also become statistically insignificant.

Table 37. Multiple regression to predict student test scores in mathematics based on teacher's academic preparation and other variables

Variable Label	Parameter Estimate	Standard Error	Probability
Intercept	39.51	0.86	0.00
Teacher's academic background			
Grade point average in math subject	0.32	0.24	0.18
Courses in mathematics education	0.13	0.38	0.74
Courses beyond calculus level	1.12	0.39	0.00
Missing data on course grades	0.34	0.90	0.71
School characteristics			
Majority receive free lunch	-1.91	0.36	0.00
Tardiness not a problem at school	0.92	0.43	0.03
Absenteeism not a problem at school	1.25	0.40	0.00
Student attitudes towards mathematics			
Not afraid to ask questions	1.60	0.23	0.00
General student attitudes			
Good luck not more imp. than hard work	1.99	0.31	0.00
Student plans for future			
Student plans to attend college	2.14	0.26	0.00
Plans academic program in HS	2.31	0.28	0.00
Expects professional/technical career	1.58	0.20	0.00
Student study habits			
Student rarely completes homework	-1.34	0.31	0.00
Frequently absent, tardy, or disruptive	-0.53	0.26	0.04
Student is inattentive in class	-1.64	0.30	0.00
Student watches less than 2 hrs of TV	1.14	0.24	0.00
Spend 5.5+ hrs per week on homework	1.54	0.24	0.00
Missing data on student homework	-0.25	0.46	0.59
Class characteristics			
Teacher says class has high achievers	6.82	0.33	0.00
Teacher assigns over 1 hr of homework	0.85	0.37	0.02
Family support			
Father wants student to attend college	1.55	0.23	0.00
Student's family has a computer	0.89	0.20	0.00
Student demographics			
Female	-1.17	0.20	0.00
African-American, Hispanic, or Native American	-3.56	0.31	0.00
Missing data on race	0.91	2.79	0.75
Bottom SES quartile	-1.39	0.25	0.00

R-square = 0.48

Table 38. Multiple regression to predict student test scores in science based on teacher's academic preparation and other variables

Variable Label	Parameter Estimate	Standard Error	Probability
Intercept	42.93	0.84	0.00
Teacher's academic background			
Grade point average in science subject	0.54	0.28	0.06
Courses in science education	-0.00	0.34	1.00
Over 40 credits in earth and physical sciences	1.10	0.45	0.02
Missing data on course grades	-0.01	0.89	0.99
School characteristics			
Majority receive free lunch	-1.50	0.51	0.00
Students place priority on learning	1.05	0.34	0.00
Student attitudes towards science			
Not afraid to ask questions	1.96	0.30	0.00
General student attitudes			
Good luck not more imp. than hard work	1.94	0.37	0.00
Student plans for future			
Student plans to attend college	1.55	0.31	0.00
Plans academic program in HS	2.58	0.28	0.00
Expects professional/technical career	1.73	0.22	0.00
Student study habits			
Student rarely completes homework	-1.68	0.35	0.00
Frequently absent, tardy, or disruptive	-0.92	0.30	0.00
Student is inattentive in class	-1.90	0.36	0.00
Student watches less than 2 hrs of TV	0.78	0.26	0.00
Spend 5.5+ hrs per week on homework	1.14	0.28	0.00
Missing data on student homework	-0.53	0.53	0.31
Class characteristics			
Teacher says class has high achievers	3.63	0.33	0.00
Textbook not too difficult to read	0.67	0.38	0.08
Family support			
Parents often discuss school programs	0.81	0.25	0.00
Father wants student to attend college	1.09	0.30	0.00
Student's family has a computer	1.10	0.26	0.00
Student demographics			
Female	-2.07	0.24	0.00
African-American, Hispanic, or Native American	-3.54	0.33	0.00
Missing data on race	-3.35	0.75	0.00
Bottom SES quartile	-2.02	0.29	0.00

R-square = 0.33

Table 39. Multiple regression to predict student test scores in science based on teacher's academic preparation in all sciences and other variables

Variable Label	Parameter Estimate	Standard Error	Probability
Intercept	42.85	0.84	0.00
Teacher's academic background			
Grade point average in science subject	0.54	0.28	0.06
Courses in science education	-0.07	0.35	0.85
Number of credits in earth and physical sciences			
Over 40 credits in earth and physical sciences	1.12	0.46	0.01
Sciences other than earth and physical sciences	0.01	0.01	0.59
Missing data on course grades	0.08	0.89	0.93
School characteristics			
Majority receive free lunch	-1.49	0.51	0.00
Students place priority on learning	1.06	0.34	0.00
Student attitudes towards science			
Not afraid to ask questions	1.96	0.30	0.00
General student attitudes			
Good luck not more imp. than hard work	1.94	0.37	0.00
Student plans for future			
Student plans to attend college	1.55	0.31	0.00
Plans academic program in HS	2.58	0.28	0.00
Expects professional/technical career	1.73	0.22	0.00
Student study habits			
Student rarely completes homework	-1.68	0.35	0.00
Frequently absent, tardy, or disruptive	-0.92	0.30	0.00
Student is inattentive in class	-1.89	0.36	0.00
Student watches less than 2 hrs of TV	0.77	0.26	0.00
Spend 5.5+ hrs per week on homework	1.14	0.28	0.00
Missing data on student homework	-0.53	0.53	0.31
Class characteristics			
Teacher says class has high achievers	3.63	0.33	0.00
Textbook not too difficult to read	0.66	0.38	0.08
Family support			
Parents often discuss school programs	0.81	0.25	0.00
Father wants student to attend college	1.09	0.30	0.00
Student's family has a computer	1.10	0.26	0.00
Student demographics			
Female	-2.07	0.23	0.00
African-American, Hispanic, or Native American	-3.54	0.34	0.00
Missing data on race	-3.45	0.78	0.00
Bottom SES quartile	-2.02	0.29	0.00

R-square = 0.33

5. Summary

Teachers' postsecondary transcripts provide a valuable source of information for investigating teacher effectiveness. Measures based on the types and numbers of courses taken, and measures based on teachers' grade point averages were both used successfully to predict teacher practices and/or teacher effectiveness; the measures based on grade point averages were the most consistently useful, while measures based on the types and numbers of courses were generally more useful for mathematics than for science. Possibly, this latter difference was due to the ability to also categorize mathematics courses in terms of the level of difficulty, which was less possible with the coding scheme used for science courses. The success of transcript-based measures of teacher preparation suggests that they might be used as one tool for making decisions on hiring teachers and assigning them to classes, and that transcript-based studies could be used to evaluate the effectiveness of the teacher education curriculum and certification requirements.

Some of the ways in which teachers' backgrounds appeared related to teachers' approaches within the classroom were in: the degree of emphasis given to selected topics in science and mathematics; the amount of time devoted to whole class instruction, individual instruction, and lab periods; and teachers' feelings of preparedness.

Teachers' academic backgrounds were also related to student outcomes. One interesting finding was the importance of advanced mathematics courses in teachers' backgrounds, even though eighth-grade mathematics might not seem to require advanced training. Training in mathematics pedagogy at best only provided an extra benefit if a background in advanced mathematics had also been obtained, but even this benefit was not statistically significant in the regression analysis. In science, the greatest differences among teachers were based on grade point averages and on teachers' backgrounds in the earth and physical sciences, while there was no difference based upon courses in science education. Certain categories of students were more likely than others to have teachers with strong academic backgrounds; however, the statistical relationship between teachers' backgrounds and student outcomes persisted even after controlling for these factors.

Though the primary focus of this report is on the professional preparation of teachers, this is certainly not the only factor, or even the most important factor, affecting student outcomes. Clearly as both Chapter 1 and the multiple regressions indicate, there are many factors affecting student outcomes; in terms of the amount of variance explained, many student characteristics are more important than teachers' professional preparation. Further, teachers' professional preparation is not necessarily the most important teacher characteristic influencing student outcomes; there are many intangible aspects of teaching (e.g., teaching style or even personality) that are difficult to measure in a standardized survey of this type, but that should be expected to be important. What can be concluded is that teachers' knowledge of the content area is important, and that a useful way of both providing and measuring that knowledge is through the teachers' postsecondary coursework in the subject area.

The failure to find the same importance for teachers' pedagogical training as for their content area training might have several explanations. One possibility is that subject area knowledge is more important than knowledge of pedagogy. This possibility seems reasonable in one sense, but clearly teachers' success depends on more than content knowledge. Another possibility is that subject area knowledge is better measured by teachers' postsecondary coursework than is knowledge of pedagogy. This could occur, for example, if knowledge of pedagogy can be acquired by other means than postsecondary education (e.g., through experience and supervision), while knowledge of the subject area may be less effectively acquired by these other means. In this sense, this report may say more about how the postsecondary education of teachers should be structured than about which factors are most important for teacher success. The reader should also remember that this study is specifically directed at teachers of eighth-grade students. One might hypothesize that content knowledge would be even more important for later grades, and that it may be less important in elementary school.

Besides suggesting that teachers' content knowledge makes a difference, the NELS data provide limited information about the mechanism by which it exerts an influence. Generally, there was not much difference among teachers based on their professional preparation in terms of the teaching techniques that were used (except for science teachers' use of labs). However, the NELS data did show a difference among teachers in their feelings of preparedness for teaching. One interpretation is that teachers with strong backgrounds communicated more favorable attitudes towards science and mathematics because they were more comfortable with the material; however, a difficulty is that little impact was found on students' attitudes. Another possibility is that the content of teachers' presentation was different when they were better prepared. The NELS data do provide some support for this latter interpretation, since there were some differences among teachers based on their professional preparation in the topics they emphasized. Though it would be desirable to have even more detailed information about how teachers' content varied, this suggests that the content of the teachers' presentation was the most critical factor.

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Appendix A
Methodological Notes

This study was conducted using the National Education Longitudinal Study of 1988 (NELS:88) database, a large national study sponsored by the National Center for Education Statistics (NCES) of the U.S. Department of Education. Designed as a longitudinal study, extensive data were collected about students and their environments in the initial base year of 1988, and in periodic followups. However, this particular study treats the study as a cross-sectional database rather than a longitudinal study, using only the original base year data and a separate teacher transcript database that was created only for that year.[1] An advantage of the focus on eighth-grade science and mathematics is that it is a time period in which the taking of science and mathematics courses is essentially universal, as compared with the twelfth grade, when many students are not taking science or mathematics courses. Also, while negative attitudes about science and mathematics are often formed even well before the eighth grade, the eighth-grade may represent one of the last and best opportunities to influence students' attitudes and their future course-taking behavior. On the other hand, eighth grade is not necessarily the time period in which teachers' academic preparation within science and mathematics is most important, since the eighth-grade courses are neither advanced nor highly specialized. (Sometimes, eighth grade is even taught by a single teacher for all subjects, rather than using specialists within each subject area as is more common in later grades.) One might speculate that extensive teacher preparation is more necessary in the twelfth-grade for such specialized courses as physics and calculus, though its impact would not reach as far in terms of the number of students affected. This appendix gives an overview of the NELS:88 database, provides some illustrative standard errors of the transcript-based measures of teachers' academic preparation, and provides information about how transcript data compare with teachers' self-reports.

Description of NELS:88

NELS:88 was designed as a nationally representative sample of 26,435 eighth-grade students in 1988 clustered within 1,052 schools. In the original base-year data collection in 1988, questionnaires were completed by the students and their parents, teachers, and schools. Four subject areas were given special attention – science, mathematics, English, and social studies – and the teacher survey was administered to two teachers from these areas for each student (with one teacher in either science or mathematics, and the other in either English or social studies). Additionally, students were given standardized tests to measure their proficiency in science, mathematics, reading, and history/citizenship. The questionnaires and tests were administered during the latter half of the school year, somewhere between February 1 and June 30, 1988 depending on the school.

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[1] The study did briefly examine whether student cognitive scores in the first followup could be related to the teacher backgrounds described here. However, as might be expected given the large number of factors affecting student achievement over the intervening time, no relationship was found.

While this study uses several components of the NELS:88 database, the primary focus is on the teacher data. Teachers were asked to provide their own evaluations of the classroom performance of each sampled student, information about the students' classes and their teaching methods, and information about the teachers' own background, activities, and opinions about the school. As a special note, while extensive information about the teachers is available, NELS:88 was designed to provide a nationally representative sample of students, not of teachers. Statistics on teachers in this report are therefore presented in terms of the number of *students* affected, rather than the number of teachers. This sometimes leads to awkward phraseology in describing the survey results.

Finally, measures of student outcomes are based on the cognitive tests in science and mathematics that were administered in NELS:88.[2] These test scores reflect not only learning that occurred in the eighth grade, but also learning in previous years. To measure the incremental gain in knowledge obtained in the eighth grade, it would have been necessary to administer tests both when students began the eighth grade and also after they completed eighth grade. The general effect of this weakness in the NELS data (common to most studies of student achievement) will be a reduced ability to relate differences in student outcomes to teachers' backgrounds.

A complementary component of NELS:88 was the Teacher Transcript Study, funded by the National Science Foundation. This component further expanded the information available on teachers by permitting analysis of science and mathematics teachers' academic preparation for teaching. For each of the 1,873 science and mathematics teachers within the NELS:88 study who gave permission, colleges were asked to provide transcripts of their academic records. Initially, only colleges identified in the NELS questionnaire as the *primary* colleges attended (i.e., the colleges granting the sampled teachers their bachelor's and graduate degrees) were contacted. When students transferred from one college to another, however, some institutions recorded all course information from students' previous transcripts, while others noted only the name of the institution(s) previously attended and the total number of credits earned. To develop a complete picture of the teachers' academic preparation, the transcripts from the primary colleges attended were used to develop a list of all colleges that had been attended, and transcripts were requested from these additional colleges. Overall, 3,088 (91 percent) of all originally requested transcripts were received, as well as 786 additional transcripts from the other colleges attended. At least one transcript was received for 1,803 (96 percent) of the 1,873 teachers for whom transcripts were requested, and all transcripts were received for 1,401 (75 percent). The 1,803 teachers consisted of 737 science teachers and 1,066 mathematics teachers.

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[2] The mathematics test had 40 items measuring skills in: simple arithmetic operations; using decimals, fractions, and percentages; understanding the relationships among these operations; and solving problems. The science test had 25 items measuring students' factual knowledge, conceptual understanding, and problem-solving skills in life science, earth science, and chemistry/physical sciences. The tests were found to be reliable, valid, and unbiased. The NCES report *Psychometric Report for the NELS:88 Base Year Test Battery* provides additional information about these tests, as well as the Reading and History/Citizenship/Government tests. The NELS:88 database provides the test scores in several formats: the number right, number wrong, number not attempted, formula score, standardized score, estimated number right using item response theory, formula score using item response theory, and quartile. For most of this report, only the standardized score is reported as a way of simplifying the presentation; except for the number not attempted, which does not appear to vary meaningfully, the choice of the scoring format does not appear to affect the results. The use of standardized testing has raised considerable controversy, and one should not expect that the tests used in NELS:88 were effective in measuring all aspects of the students' performance. Nevertheless, the point of this paper is that many systematic differences in student achievement can be found using the test data, including in combination with the teacher transcript data.

The NELS:88 data were reweighted to correct for several types of nonresponse. First, in the NELS data the number of students with mathematics teachers originally weighted to 1,395,825, and the number with science teachers originally weighted to 1,377,751, rather than the 3,008,080 for the full sample; this was primarily due to the half-sampling used in NELS (in which either a student's mathematics teacher or the student's science teacher was selected for the study, but not both), but also to some nonresponse among the teachers. Separate multipliers were created for mathematics and science teachers to reweight each total to the full amount, using the percentage of minority students at the school, the percentage of students receiving free lunches, and the grade span of the school as poststratification variables; additionally, the weights were trimmed to lessen their variability. Second, the transcript component of the survey also introduced nonresponse, either because the teacher refused permission to collect the transcript, or no transcript was collected. Again treating science and mathematics teachers separately, additional multipliers were calculated using the teacher's birth year, the teacher's race, and the geographic region of the school as poststratification variables; the resulting weights were again trimmed if they were greater than 1,000.[3]

Each course listed on a received transcript was coded into one of 92 two-digit subject categories based upon the Classification of Instructional Programs (CIP) coding system. Courses in science or mathematics were coded in additional detail, using a total of 96 four-digit codes.[4] For the purposes of classifying courses as science courses, courses in the life sciences, physical sciences, chemistry, geology, physics, general science, and science technologies were included. Courses in computer science were not classified as either science or mathematics courses. Courses were classified as mathematics or science education courses if they were specifically concerned with teaching methods within mathematics or science; general courses in education were not included.

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[3] Without the multipliers, the weighted numbers of students with teacher transcript data were 925,915 for mathematics, and 984,750 for science.

Reliability of Survey Estimates

The findings presented in this report are estimates based on the NELS:88 sample and, consequently, are subject to sampling variability. If the teacher questionnaire had been sent to a different sample, the responses would not have been identical; some figures might have been higher, while others might have been lower. The standard error is a measure of the variability due to sampling when estimating a statistic. It indicates how much variability there is in the population of possible estimates of a parameter for a given sample size. Standard errors can be used as a measure of the precision expected from a particular sample. If all possible samples were surveyed under similar conditions, intervals of 1.96 standard errors below to 1.96 standard errors above a particular statistic would include the true population parameter being estimated in about 95 percent of the samples. This is a 95 percent confidence interval. For example, the estimated percentage of students whose teachers had a grade point average higher than 3.0 in mathematics is 39.78 and the estimated standard error is 0.66. The 95 percent confidence interval for this statistic extends from 39.78 - (0.66 times 1.96) to 39.78 + (0.66 times 1.96), or from 38.49 to 41.07 percent. This means one can be 95 percent confident that this interval contains the true population value. Estimates of standard errors for the estimates were computed using a Taylor series approximation using SUDAAN. Some key statistics and their estimated standard errors are shown in Table A-1. Generally, because of the large sample size used in NELS, standard errors were small even for subgroups of students or teachers.

Because of the complex sample design that was used for NELS:88, ordinary statistical procedures that assume a simple random sample are not appropriate. Also, the computation of standard errors is further complicated by the design in which multiple students may be associated with a single mathematics or science teacher. A Taylor series approximation technique for computing standard errors was used to remedy both problems, and was used both for the standard error estimates in Table A-1 and for the regression estimates in Chapter 4. Another approach would be to use hierarchical linear modeling. However, because the variables

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[4] Additional information on the coding and on other aspects of the research methodology can be obtained from the *Methodology Report* for the NSF/NELS:88 Teacher Transcript Study.

Table A-1. Selected standard errors for transcript-based measures of teachers' academic background

Teachers' background	Mathematics		Science	
	Estimate	Standard error	Estimate	Standard error
Mean GPA in subject area				
2.5 or lower	31.48	0.62	37.47	0.64
2.5001-3.0	28.73	0.61	31.82	0.61
Higher than 3.0	39.78	0.66	30.71	0.60
Types of courses taken				
No mathematics courses	4.70	0.27	--	--
Mathematics education only	5.01	0.26	--	--
Mathematics only				
Calculus level or below	6.98	0.32	--	--
Some advanced courses	17.50	0.51	--	--
Both mathematics and mathematics education				
Calculus level or below	15.18	0.44	--	--
Some advanced courses	50.63	0.63	--	--
No science courses, or science education only	--	--	4.68	0.26
Science only				
40 credits or less	--	--	26.70	0.56
More than 40 credits	--	--	9.94	0.38
Both science and science education				
40 credits or less	--	--	21.81	0.52
More than 40 credits	--	--	36.87	0.60
Mean student test score by teachers' grade point average in subject				
2.5 or lower	49.20	0.24	49.21	0.22
2.5001-3.0	49.94	0.26	50.84	0.23
Higher than 3.0	51.87	0.22	51.44	0.25
Mean student test score by teachers' background in science				
No science courses, or science education only	--	--	47.79	0.54
Science only				
40 credits or less	--	--	50.37	0.26
More than 40 credits	--	--	51.23	0.45
Both science and science education				
40 credits or less	--	--	50.04	0.27
More than 40 credits	--	--	50.45	0.21
Differences in mean student test scores				
Teachers with advanced math courses and mathematics education versus those without advanced math but mathematics education	2.56	0.35	--	--
Teachers with advanced math versus those without, among teachers with no mathematics education	2.69	0.58	--	--
Teachers with GPAs above 3.0 versus those with GPAs of 2.5 or lower	2.67	0.33	2.23	0.33
Teachers with more than 40 credits in science versus those with up to 40, among teachers with no science education	--	--	0.86	0.52
Teachers with more than 40 credits in science versus those with up to 40, among teachers with science education	--	--	0.41	0.35

SOURCE; NSF/NELS:88 Teacher Transcript Analysis measuring teachers' academic background are only used directly, and not in interaction with student-level explanatory variables, hierarchical linear modeling has no advantages over Taylor series approximation techniques and would require different (Bayesian) statistical assumptions.

Survey estimates are also subject to errors of reporting and errors made in the collection of the data. These errors, called nonsampling errors, can sometimes bias the data. While general sampling theory can be used to determine how to estimate the sampling variability of a statistic, nonsampling errors are not easy to measure and usually require either conducting an experiment as part of the data collection procedures or using data external to the study.

Nonsampling errors may include such things as differences in the respondents' interpretation of the meaning of the questions, differences related to the particular time the survey was conducted, or errors in data preparation. Presumably, nonsampling errors would be greater for questionnaire data than for that obtained through the teacher transcripts, because the coders who processed the transcripts could participate in a uniform training session and could share in the use of reference tools for assigning course codes; nevertheless, inconsistencies could still appear between two different coders, or even from one transcript to another when both transcripts are processed by the same coder. For both the NELS:88 questionnaire data and the transcript processing, a variety of steps were taken to reduce the likelihood of nonsampling errors; these include pretests of both the NELS questionnaires and of the transcript processing, as well as computer edits to check for inconsistencies in responses or coding.

Comparison of Transcript-Based Measures Against Teachers' Self-Reports

While transcripts offer a uniquely detailed and accurate record of teachers' academic preparation, there also are disadvantages connected to transcripts: they may require a separate data collection (as with NELS:88), though there may also be times where a transcript study could completely replace a survey of teachers; they can be expensive to collect and code; and they are subject to inconsistencies among institutions in terms of the types of information provided. Thus, one might question whether transcripts provide information that could be more easily obtained through other means, or whether for those studies where transcript data are not available, an appropriate surrogate might be found from teachers' self-reports.

NELS:88 was not specifically designed to measure the accuracy of teachers' reports, and thus did not attempt to get detailed descriptions from teachers of their academic backgrounds.[5] However, it did request information on teachers' undergraduate and graduate degrees, on their major field of study for both types of degrees, and on their certification. These measures are not capable of providing the same level of detail as the transcript-based measures (especially with regard to the grade point average within science or mathematics, which was not collected by NELS and could not be collected with a high degree of precision), but they are interrelated.

Academic Degrees

Because the major field of study for a teacher when earning an undergraduate or graduate degree indicates the teacher's area of specialization, it is a logical simplified measure of a teacher's academic background.

Science. Table A-2 shows that teacher's reports of having majored in science are closely related to the number of credits they took. A much higher percentage of students had teachers who took more than 40 credits in science if their teachers majored in science as an undergraduate (78 percent) than if their teachers minored in science (29 percent) or if their teachers neither majored nor minored in science (14 percent).[6] Similarly, there was a large difference based on teachers' graduate majors, though teachers with graduate degrees tended to have more extensive backgrounds in science.[7] At least two-thirds of the students had teachers with more than 40 credits in science if their teachers either majored in science for their graduate degree (73 percent) or minored in science (68 percent), while roughly one-third (34 percent) had teachers with such backgrounds if the teachers had neither majored nor minored in science.

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[5] A separate transcript study, using the Schools and Staffing Survey, did seek to answer these types of questions, with teachers being asked to provide both some general information about their background, as well as the number of courses and credits in specific subject areas. The study found that teachers generally were accurate on the most basic types of questions (such as the degrees they had earned, or their major field of study), but that the more detail that was requested (e.g., in terms of the number of courses or credits) or the more secondary the type of information requested (e.g., requesting information on their background in their second teaching assignment for those teachers who taught courses in more than one area), the more likely the teachers were to make mistakes. Additionally, some teacher errors in reporting were probably due to errors in the ways in which they categorized the information (e.g., classifying geography within geology/earth science rather than as a social science), rather than reflecting problems in recall or bias. See Chaney, *op. cit.*

[6] The NELS data were adjusted by combining separate questions on teachers' majors and minors, and only counting teachers as having minored in science if they did not also major in science. Otherwise, if the NELS data are used in their original form (a yes/no question on whether the teacher minored in science), then both categories include teachers who majored in science, and information on the teacher's minor fails to provide useful information.

[7] The measure of credits includes both undergraduate and graduate courses, so one reason for the teachers to have a more extensive background is that the credits are being counted over a greater number of years of education.

Table A-2. Comparison of teachers[1] self-reports of their academic background with transcript-based measures

Transcript based measures	Percentage of teachers with given academic background among those reporting					
	Undergraduate			Graduate		
	Major in subject area	Minor in subject area[2]	Neither	Major in subject area	Minor in subject area[2]	Neither
Mathematics						
Level reached						
No courses	3	3	23	0	7	14
Calculus or below	1	22	49	5	25	27
Some advanced courses	96	75	28	95	69	59
Grade point average in mathematics						
2.5 or below	23	39	37	6	29	42
2.5 - 3.0	29	30	27	29	35	27
Higher than 3.0	48	31	36	64	36	32
Science						
All sciences						
40 credits or less	22	71	86	27	32	66
More than 40 credits	78	29	14	73	68	34
Earth and physical sciences						
None	6	7	22	6	6	7
Up to 5 credits,	5	14	18	8	5	12
5.1 - 20 credits,	29	46	46	28	35	41
20.1 - 40 credits	39	29	12	26	34	24
Over 40 credits	21	5	2	32	20	6
Grade point average in science						
2.5 or lower,	36	37	40	20	25	42
2.5001 - 3.0,	33	39	25	33	39	29
Higher than 3.0	31	24	35	48	37	29

[1] Percentages are based on those teachers with graduate degrees.

[2] Percentages are based on those teachers who reported a minor in the subject area, and a major outside of the subject area.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

While information about a science teacher's major proved reasonably powerful as a general measure of a teacher's background (as might be expected, since 40 credits largely correspond to the requirements for a major), it performed less well than the more precise transcript-based measures. For example, it was already noted that a teacher's background in the earth and physical sciences might be more relevant for an eighth-grade teacher than his/her background in all of the sciences, but the NELS questionnaire did not collect information about whether the teacher's major was in the earth or physical sciences.[8] The information provided by NELS on the teachers' majors is less adequate as a surrogate for this information: only one-fifth (21 percent) of the students had teachers with over 40 credits in the earth and physical sciences if their teachers had majored in one of the sciences. Still, teachers were more likely to have a strong background in the earth and physical sciences if they majored or minored in the sciences than if they did not: 60 percent of the students had teachers with more than 20 credits in the earth and physical sciences if their teachers majored in the sciences, compared with 34 percent if their teachers minored in the sciences and 14 percent if their teachers neither majored nor minored in the sciences.

If teachers' strength in science is measured in a different way – through their grade point averages in the sciences--then teachers' self-reports about their degrees and majors have little value as a surrogate. Students were somewhat evenly divided in how their teachers were distributed among the three grade categories regardless of the teachers' majors or minors, except that students were relatively likely to have teachers with a high grade point average (above 3.0) if their teachers earned a graduate degree with a major in science (48 percent, compared with 29-37 percent if the teachers had not majored in science).

Mathematics. Because the somewhat hierarchical structure of mathematics allows a different measure than simply measuring the total number of credits, the transcript-based measures perform somewhat differently when compared with teachers' self-reports on their degrees and majors. Generally, more teachers should be expected in the highest category for mathematics than for science, since a teacher could take advanced courses without reaching 40 credits in mathematics, and students who majored in other areas could attain this level in mathematics while satisfying their responsibilities in other subject areas. Thus, as might be expected, among those students whose teachers majored in mathematics as undergraduates or graduate students, essentially all had teachers who had taken advanced mathematics courses (95-96 percent).[9] Further, 75 percent of students had teachers who took advanced courses as undergraduates (if the teacher had minored in mathematics), and 28 percent had teachers who took advanced courses (if the teacher had neither majored nor minored in mathematics). Nevertheless, the general pattern remains that despite the higher percentages in the top category, students were most likely to have teachers who had taken advanced courses if their teachers had majored in mathematics, and least likely if their teachers had neither majored nor minored in mathematics.

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[8] The questionnaire could have been designed to collect such information. However, two advantages of transcript-based measures are the flexibility to redesign a measure after data collection is completed, and the greater accuracy of transcripts if the alternative is to request highly detailed responses by the teachers.

[9] A possible explanation for the few teachers who had majored in mathematics without taking advanced courses is that their major was actually in an area such as mathematics education.

With respect to teachers' grade point averages in mathematics, as with science there generally were substantial numbers of students with teachers in each category whether or not the teacher majored or minored in mathematics; however, there was a greater likelihood than in science that a teacher who majored in mathematics had a mathematics grade point average above 3.0. Essentially half (48 percent) of the students whose teachers majored in mathematics as undergraduates had teachers with mathematics grade point averages above 3.0, compared with 31 percent in science.

Teacher Certification

Teacher certification might also be assumed to be an indicator of a teacher's academic background, though a teacher might be certified through his/her background in teacher education rather than necessarily in the subject area being taught.

Science. A large majority of eighth-grade science students had teachers who were certified in science (84 percent), so knowledge about certification cannot provide as discriminating of a measure of teachers' backgrounds as measures based upon transcripts (Table A-3). However, certification was strongly related to teachers' academic training in science. Essentially all students whose teachers took more than 40 credits in science had teachers certified in science (99-100 percent), compared with a much smaller percentage of students whose teachers took 40 credits or less (68-75 percent). Similarly, as a general rule, the higher the number of credits the teacher earned in the earth and physical sciences, the more likely students were to have a teacher who was certified in science. Certification was not as strongly related to teachers' backgrounds in terms of their grade point average in science; oddly, students were most likely to have certified teachers if their teachers had a grade point average between 2.5 and 3.0 (94 percent versus 81-82 percent).

Table A-3. Teachers' academic backgrounds and their certification in science or mathematics

Teachers' background	Certified in subject area		Percentage certified in subject area within undergraduate major		
	Yes	No	Major in subject area	Minor in subject area[1]	Neither
Mathematics					
Total	82	18	98	87	55
Types of courses taken					
No courses in mathematics[2]	--	--	--	--	--
Courses in mathematics education only[2]	--	--	--	--	--
Courses in mathematics but not in mathematics education					
Calculus level or below	55	45	100	66	51
Some advanced courses	88	12	100	91	59
Courses in both mathematics and mathematics education					
Calculus level or below	67	33	100	84	58
Some advanced courses	93	7	98	88	73
Grade point average in mathematics					
2.5 or lower	82	18	100	89	55
2.5001 - 3.0	86	14	96	95	55
Higher than 3.0	87	13	100	76	68
Science					
Total	84	16	100	88	57
Types of courses taken					
No science courses, or science education only[2]	--	--	--	--	--
Science courses only					
40 credits or less	75	25	100	86	53
More than 40 credits	100	0	100	96	100
Both science courses and science education					
40 credits or less	68	32	100	83	51
More than 40 credits	99	1	100	100	92
Credits in earth and physical sciences					
No credits	64	36	100	71	46
Up to 5 credits	59	41	100	74	33
5.1-20 credits	83	17	100	89	62
20.1 - 40 credits	97	3	99	97	83
Over 40 credits	100	0	100	100	100
Grade point average in science					
2.5 or lower	82	18	100	83	53
2.5001 - 3.0	94	6	99	95	82
Higher than 3.0	81	19	100	91	48

[1] Percentages are based on those teachers who reported a minor in the subject area, and a major outside of the subject area.
[2] Too few cases for reliable estimates.
SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Certification was also related to teachers' majors and minors, though even in combination with information about majors and minors, it failed to describe the extent of variation among teachers as adequately as transcript-based measures. There was a general pattern that certification rates were highest among teachers who were majors (for them, 100 percent of students had teachers who were certified), next highest among minors (88 percent), and lowest among teachers who neither majored nor minored in science (57 percent). However, the fact that a majority of students whose teachers neither majored nor minored in science still had teachers certified in science suggests that certification is not an automatic indicator of teachers' background in science. Further if the transcript-based measures of teachers' backgrounds are examined, though there was typically a pattern of increased certification rates when teachers had stronger academic backgrounds, there were still large percentages of students whose teachers were certified despite having relatively weak science backgrounds.

Mathematics. The same general findings concerning certification of science teachers were also true for mathematics teachers. Certification was strongly related to the types of course that teachers took, with students' teachers more likely to be certified if they took advanced mathematics courses (88-93 percent) than if they only took courses at the calculus level or below. As with science, however, teachers' grade point averages in mathematics were not strongly associated with teachers' certification.

Again as in science, certification rates were highest if teachers were majors in mathematics (98 percent), next highest if they were minors (87 percent), and lowest if they were neither majors nor minors (55 percent). Again, teachers' certification failed to strongly discriminate among teachers based on their backgrounds; teachers often were certified in mathematics even if they had weak backgrounds in mathematics, though they were more likely to be certified as the strength of their backgrounds increased.